SCIENTIFIC RESEARCH AND SOCIAL NEEDS

THE LIBRARY OF SCIENCE AND CULTURE

Edited by Prof. H. Levy

The outstanding feature of the present age is the extent to which the life of Man is affected by the remarkable growth of science. Not only has the development of scientific processes had a profound and disturbing effect on social conditions, but the extension of scientific knowledge and the increasing application of the scientific method in all directions have transformed our mental outlook and evoked new conceptions in history, ethics, philosophy, religion, and every phase of culture

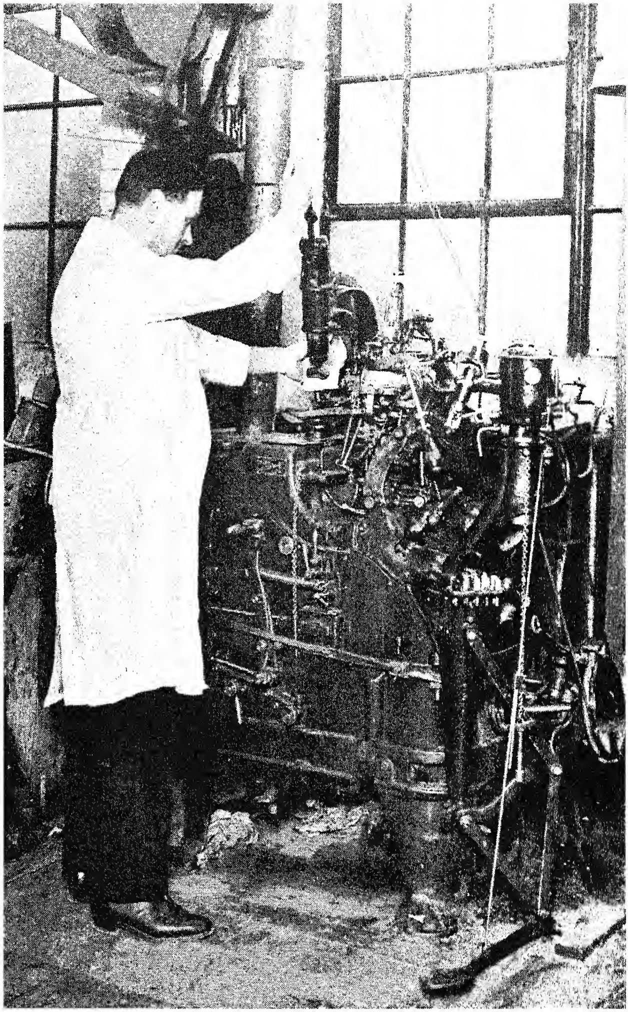
The Library of Science and Culture is designed to present to the general reader a picture of the world, both of action and of thought, as science is shaping it. It will reveal how mankind has sought in science the means of satisfying its varied needs; and how, in turn, science is stimulating fresh aspirations, inspiring loftier deeds of progress, and awakening hopes of increasing mastery over the destiny of the race

Each volume will deal with one aspect of modern thought, or with a group of aspects. Together they will provide a comprehensive survey of the ever-widening empire of science, providing up-to-date information on the most recent developments and indicating the lines upon which further achievement is expected.

After Chick and Dalyell.

What vitamins can do. Twins in a Vienna infants' home in 1921. The little girl at the left, six months before the photograph was taken, had both rickets and scurvy. She was badly under weight, could neither stand, sit, nor talk, and at twenty-two months had only four teeth. After six months' treatment with a diet rich in vitamins, she was healthy, active, and cheerful, with twelve teeth. Her twin brother on the right had suffered in the same way, but had been in another ward where no special dietetic treatment was given. He remained unable to sit without support, had no energy, and gave no signs of intelligence. (*See* p. 100.)

By courtesy of "British Medical Journal."



Invention in industry. An automatic edge-setting machine, used to produce the hand-burnished edge round the sole of a shoe. The edge of the sole is made to move backwards and forwards past a rapidly vibrating electric " iron," which consolidates the leather and forces wax into its pores. The machine is controlled through tiny " feelers " in contact with the sole-edge, which ensure that the " iron " shall follow the edge exactly, whatever the shape or size of the shoe. (*See* p. 132.)

By courtesy of the British United Shoe Machinery Co. Ltd.

SCIENTIFIC RESEARCH
AND
SOCIAL NEEDS

BY

JULIAN HUXLEY

With an Introductory Chapter by Sir William Bragg, F.R.S., and Discussions with Professor H. Levy, Sir Thomas D. Barlow, K.B.E., and Professor P. M. S. Blackett, F.R.S.

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FOREWORD

SCIENCE AND SOCIAL NEEDS

IF Society has often been blind to the possibilities of Science, in its turn Science has been a blind force in social life. Lauded on one side for the profusion with which it has showered its gifts on mankind, it is regarded on the other with rising suspicion as a possible cause of social dislocation. Electric power, lighting, heating, traction, sound films, wireless—these and numerous other social amenities have been rendered possible by a single discovery in physical science, and they in their turn have produced far-reaching repercussions in the life of the community. They have compelled readjustments in modes of life, in habits of thought, and in the cultivation of tastes. They have consistently undermined religious dogma. They have radically altered the incidence of employment and of production in all but the most agricultural of communities. They have altered the distribution of populations and stimulated the industrialization of vast areas of the earth hitherto untouched by mechanization and commerce.

Here on a wide scale is a field of Applied Science in the true sense of the term. To accord blame or credit to the selected few scientists who contributed

most to setting this social avalanche in motion would be futile. However conscious they were of the scientific implications of their work, they could not predict its social effects. If, however, such tremendous experiments in applied science are to be tried on mankind, it is of first importance to examine in what circumstances these forceful activities are aroused, the nature of science itself, and its cultural and social significance.

As a first, almost a pioneer, step towards accumulating modern data on these matters, this series of investigations and discussions conducted by Professor Julian Huxley stands out as something unique. He has visited research laboratories and university departments of all kinds, from those concerned with the purest of science to those involved in direct production; and the innumerable channels through which the fund of knowledge pours out into its multitude of social applications have been made apparent.

It will not be contended that the data are complete, or the analysis and conclusions in any sense final. What can be asserted without question, however, is that here at any rate is one of the first surveys of science in relation to many aspects of social needs. If we are to become conscious of our own capacities as a community, we must understand these many-sided implications. This does not mean that a knowledge of our capacities will make it possible to plan the running of a community on scientific lines. Nations are not isolated so completely from one another that

each can be dealt with on its own. Because they interlock, piecemeal planning is likely to accentuate rather than alleviate our difficulties. It is essential in spite of this, and because of this, that we should understand the interactive nature of Science and Society.

This is the first volume of The Library of Science and Culture, which it is hoped may assist to that end.

H. LEVY.

AUTHOR'S PREFACE

READING through the proofs of this little book, which attempts to give some connected picture of my "tour of British Science," I realized afresh how small a fraction of the whole I had really been able to see, still less to write about—and yet at the same time was surprised how much ground, both physical and intellectual, I had really managed to cover in those crowded weeks. Clive was surprised at his own moderation: I became surprised at my own activities!

During that time I came to realize the vast amount of scientific knowledge and practical wisdom diffused through this country, of which up till then I had been at best dimly aware; and to feel my own ignorance and limitations very acutely. I became more than ever impressed with the fact that both our existing structure of civilization and our hope of progress are based on science, and that the lack of appreciation and understanding of science among business men, financiers, educational authorities, politicians, and administrators was a serious feature in our present situation.

Almost equally serious, however, is the absence of a broad scientific outlook on life, too often to be noted in the scientific specialist as well as in the layman. For if I may repeat here what will be found stressed

in several places in the pages that follow, the most important of all the lessons I learned from my tour was that science occupies an anomalous half-and-half position in our affairs to-day. On the physico-chemical side it is very highly developed, both in its pure and applied aspects; the biological sciences are rapidly growing, though there is still a lag in their applications; but the psychological and social sciences receive hardly any public support and find hardly any practical application. The next step must be to apply science all round—to the organization of society and to various separate social problems such as education, religion, the penal system, statistics, health, and so on. And we do not only need scientific research in the narrow specialist sense: we need also the scientific spirit and method, in the shape of careful planning. Planning is much in the air at the moment: we must make sure it is scientific planning, with an experimental basis wherever possible, and always in touch with scientifically ascertained fact.

The same applies to the scientific movement as a whole. For science too is a social activity, and itself demands scientific study. There is here a lesson for scientists to learn, as well as one for statesmen and the lay public.

I must not forget all those who helped me with information, advice, and hospitality. Space forbids individual acknowledgments: so I must include all, whether from Government Departments, Universities,

Research Stations, or industrial laboratories, in this brief but sincere expression of my thanks. Nor must I forget the B.B.C., who originally suggested that I should undertake this survey of British science. For that suggestion, and for the facilities and stimulus provided by their Talks Department, I should like to make this public expression of gratitude. The basis of this present book is furnished by the twelve wireless talks and discussions I gave for the B.B.C. But these have been very considerably revised and amplified to adapt them for publication in book form, so that this volume contains more than half as much again as the talks.

Finally, I should like to acknowledge the valuable help I have had from my secretary, Miss P. Coombs, in seeing the book through the press.

JULIAN HUXLEY.

King's College,
London.
March, 1934

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CHAPTER I

SCIENCE: FRIEND OR ENEMY?

BY SIR WILLIAM BRAGG

MR. JULIAN HUXLEY has undertaken a very remarkable tour in this country. He is studying, broadly speaking, the influence which scientific discovery is exerting upon our lives. He has examined the methods by which research is carried on in various places and for various purposes. He will tell us of the results. And especially he will consider the relations of science to social questions: questions that we are all asking to-day. Is scientific research drawing us together or forcing us apart? Is it to be commended for
our needs or blamed for causing unemployment? Does it help to bring peace between the nations, or war? Does it add to mankind's vision or restrict it? If it is solving some problems, is it perhaps raising others still more difficult and troublesome?

How tremendous these questions are we have only recently begun to realize. There is division among us as to how they should be answered. For some reasons it seems that we should make every use possible of the new knowledge which is poured upon us; and apparently there are other reasons for refraining. It seems foolish to throw away new methods which give us better results for less labour or a new understanding which makes the world a richer place for us. On the other hand, men have used new knowledge for the

B

purpose of constructing machines; and the machine, though extremely useful, has often produced unemployment, which is an evil, however temporary it may be. Is there a real solution, or can we do no more than compromise? At the 1933 meeting of the British Association in Leicester, Sir Frederick Gowland Hopkins considered the matter very seriously, and so did Sir Josiah Stamp in an evening address. The year before, at York, Sir Alfred Ewing was not a little pessimistic on the subject. The tone at Leicester was rather more cheerful. But we do not want such questions to be considered by a few talented men only. These are matters for us all, because they involve our social relations, our well-being, and our content. We are glad of the facts that Mr. Huxley will be able to lay before us.

I have been trying to think how I might help to prepare the way for Mr. Huxley and contribute to a better appreciation of what he is going to tell us. I am going to ask you to make an imaginary journey with me round the little corridor beneath the seats of the theatre of the Royal Institution. On a small scale it is rather like the underground spaces of Piccadilly Circus, and it is lined with well-lit show-cases like those of a big store. In these cases are shown the pieces of apparatus which have been used by great experimenters of the last hundred years, particularly by those who have worked in the Institution. Everything that is shown suggests to us some aspect of the big questions we have before us.

We halt before the first case: it goes back to the beginning of last century. There is an old model of a fireplace in it, another of a boiler, a cooking-pot, and

some instruments for measuring heat. They are all that is left of the work of a certain Count Rumford, an American of extraordinary talents who sided with the British during the War of Independence. He lived afterwards in England and then in Munich, where he won great honour and was made a Count of the Holy Roman Empire. To scientific men, especially to engineers, he is known for his fundamental work on heat. But as I look, with you, at the relics of his experiments, I do not want to tell you of his researches so much as of the ideas that fired his imagination. For he was one of the first of those who tried to use scientific knowledge in a scientific way in the interest of economy, and especially for the relief of the discomforts of the poor. I use the word "poor" in the sense that was common in those days.

He wanted to gather together in one place models which would show how all sorts of common things should be made and used His writings describe, with extraordinary foresight, the modern type of Science Museum, such as the one in South Kensington, which has recently become so popular. He was particularly interested in the economy of fuel, and waged war on the ill-designed grates and chimneys which filled rooms and streets with smoke. It was that which brought him in contact with Sir Thomas Bernard, another man of great interest from our point of view. For he was the active member of a remarkable body of men who met and worked under the grandiloquent title of a "Society for Improving the Condition and adding to the Comforts of the Poor." The very title is illuminating. It was unique in its day: the one Society in London apart from religious

bodies which set out to relieve distress by the systematic employment of scientific knowledge. There was certainly plenty to do There were very few hospitals, and some of those existing had terrible records Bernard gives an account of the conditions in a little book, *Pleasure and Pain,* which he wrote in 1818, though, curiously enough, it was not published until 1930. His Society founded new hospitals and charitable institutions of many kinds and strove to correct existing abuses. As might be expected, he met with many difficulties, which he describes with some humour. Bernard was treasurer of the Foundling Hospital at the time, and with Rumford's help he set the kitchens and heating arrangements in order. But when the same economies were introduced into Christ's Hospital they broke down, because the cook had the perquisite of the dripping and her husband the perquisite of the cinders.

You see, then, that this window in the corridor takes us back to early days of organized endeavour to apply scientific knowledge to the relief of distress. And our minds run on to survey all the work in the cause of health that has been done since then: the innumerable hospitals where every scientific advance has been examined for its possible usefulness, the Boards of Health, and all other bodies which have laboured to prevent disease. No one of us is likely at this point to say that it would have been better if in this direction there had been no search for knowledge and no wish to apply it.

Let us move to the next window. Rows of lanterns of a curious appearance stand on its shelves. They were made by Sir Humphry Davy. He had been asked to solve the problem of the lighting of "fiery mines." In

the search for coal it had become necessary to penetrate into regions where explosive gases were to be found; and many terrible accidents had occurred Davy's miner's lamp was the result of a few weeks of experiment, and provided the solution that had been asked for Beside the lamps stands the photograph of a grateful letter from miners of Northern England: unable to read or write, they have put crosses to their names. Others, like Stephenson, were at the same time groping their way to the same sort of solution.

There also stands one of the machines which the small boys turned continually, causing a steel wheel to strike showers of sparks from a flint which they pressed against it. The sparks were not hot enough to fire the gases, but their feeble light enabled the miners to get on with their work. With the aid of Davy's device, mining was, and still is, carried on in comparative safety where otherwise nothing could be done It stands for all those labours which in the past century have aimed at the safety of the mine; and is itself one of the most effective of all those devices. That is good, let us say. But with every improvement in method comes an increase in the extent of the work and in the numbers of the men who live by it Millions of people in South Wales, in the northern counties, and elsewhere, have been put in the way of earning their living In these times a slump has come: the whole effort is thrown out of gear, and we see the pitiful spectacle of widespread unemployment in the mining areas. What are we to say? Would it have been better if the miner's lamp had never been invented and the progress of coal-mining had been stayed? Would it be well to take the warning and to stop all such

attempts to improve the conditions of working, on the ground that a rapid rise in employment may result in a fall to be dreaded?

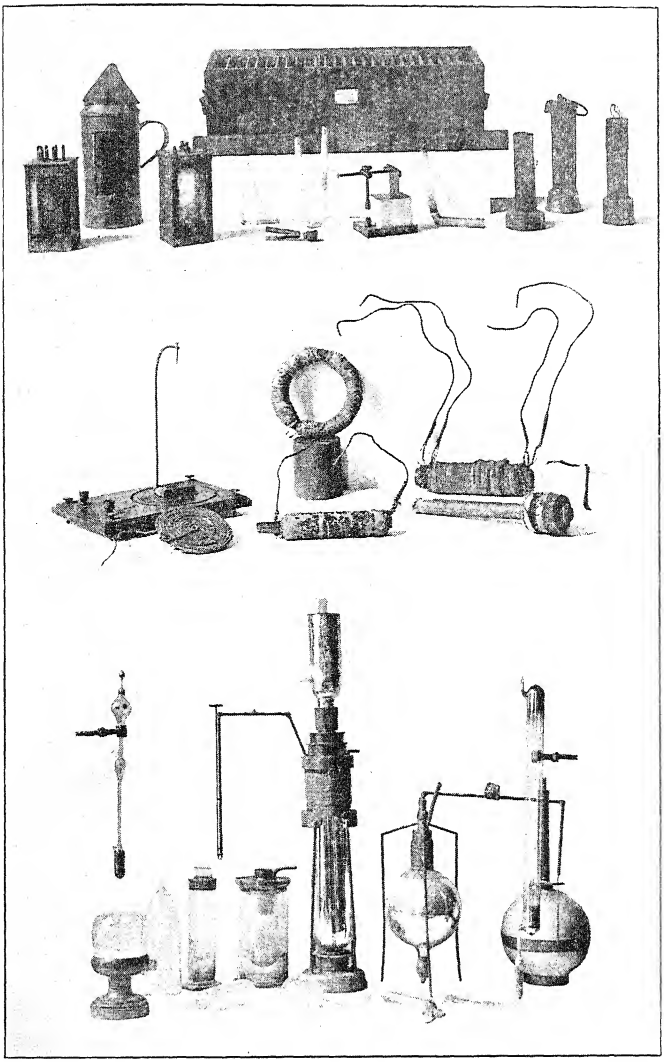
Here is a window in which there are many things of great interest A small tube contains a little transparent liquid, which, we learn from the card that lies beside it, is some of the first benzene ever made A hundred years ago gas for lighting purposes was carried round in cylinders. Curious residues were found in the cylinders after use; and Faraday (in 1825) extracted the new liquid and determined its composition. What visions the sight of it conjures up! Benzene is the central figure of organic chemistry. On that chemistry depends in the first place all our knowledge of the materials of living bodies: all our attempts to understand and fight disease Industrially, the dye industry hangs on benzene and the substances derived from it. I may remind you that since the War the dye industry in this country has advanced greatly, and employs its hundreds of thousands directly, and indirectly ten times as many. And at the same time we may link to organic chemistry all other chemistries, tremendously powerful in these days. Do we wish that chemistry had never functioned? Would we give up anæsthetics, for example? Some of us are old enough to remember the days of our childhood when we parted with our teeth with nothing to help us through; and we wondered how they stood it who had to bear the pain of long and serious operations in the hospital. But, then, the same chemistry has given us the poison gases of warfare. "Sorry, sir," said the auctioneer to the would-be purchaser, "but if you want the parlour lamp you've got to take the garden roller. They're in the same lot."

Here, besides the benzene, are some cups and moulds of wood and wax. They recall to me the whole manufacture and use of the submarine cable I can picture the multitudes engaged in the collection of the insulating materials in the forests and the mines, the preparation of the copper and the steel, the winding and the laying of the cable, and the use we all make of it. The moulds at which we are looking were used by Faraday in his electrical experiments, and it was on his results that William Thomson was able to advise the promoters of the Atlantic cable as to its proper design. Not that Faraday was thinking of cables or telegraphy when he made the experiments. he was concerned only with the basic laws of electricity.

This reminds us of the differences, such as they are, between pure and applied science. Just as we grow in our gardens annuals for our immediate pleasure, and plant shrubs in the herbaceous border to reward us in a few years' time, while, with longer foresight, we plant forests or give the natural timber the opportunity to grow, so it is with the growth of knowledge Often we ask for some immediate solution of a problem; and that is particularly true in the industry of the small manufacturer. The bigger man can look further ahead. And when it comes to the advances of science into the unknown, long vision is wanted, for no one knows if any use can be made of what is found. Only governments, universities, or large-scale private industry can be expected to give attention to it Faraday works out the laws of electricity: that is in the background of the picture. The designer looks for the best form to give to the cable and the best materials of which to make it. That is the middle distance. For instance,

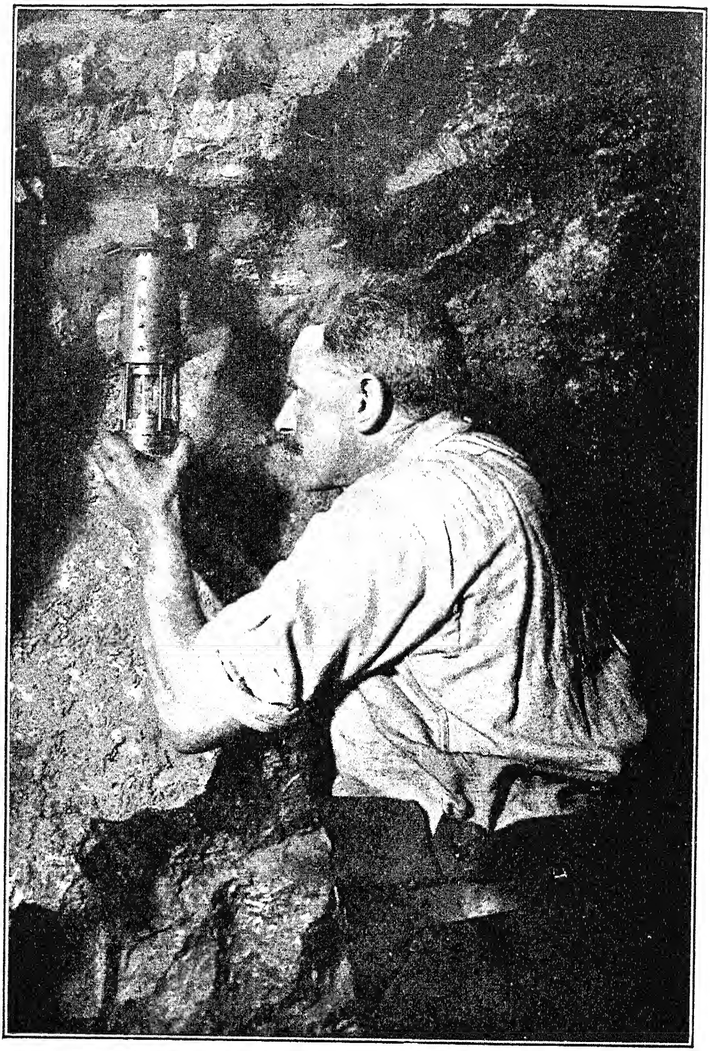
the research workers of the Non-Ferrous Metals Research Association have recently discovered an alloy which replaces the lead covering, with the most remarkable results in the way of economy. The pure lead covering wore and broke as its loop swung to and fro in the tidal currents, but the new covering is more elastic, and in other ways is as good as the old. Lastly, there are the innumerable technical difficulties that occur in manufacture and laying. These are in the foreground.

Let us turn now and look into a window on the other side of the corridor. There is a glass case containing a number of glass tubes. They are the remains of what Faraday used when he condensed certain gases into liquids under the influence of cold and pressure. On this work, extended by others, rests the modern industry of refrigeration. We have learnt how to use cold in order to keep our food supplies from going bad. We have learnt how to bring food cheaply and safely from abroad, being unable to produce it in sufficient quantities at home. If it were cut off, the necessary readjustments would be terribly painful. Undoubtedly, however, this foreign supply keeps down home prices and makes it difficult for our own growers to earn a living. How far ought we to go with our efforts in this direction? It was stated recently that the avoidance in the waste of fruit during its voyage from South Africa to England amounted to one whole shipload in the year; which improvement was due to research into the right conditions of cold storage. Is this a good result or a bad one? And this reminds us of many such perplexities. Taking the world as a whole, it seems impossible to use all that is produced. When



Research in pure science may have practical results of the greatest importance. Photographs of the actual apparatus used at the Royal Institution by three great British men of science. Above, apparatus used by Sir Humphry Davy: on the right, the earliest model for safety lamps in mines. Centre, apparatus used by Faraday, which laid the foundation of the whole electrical industry. Below, apparatus used by Sir James Dewar, including the prototype of the modern thermos bottle. (*See* pp. 2–11).

By courtesy of the Royal Institution.



The fruits of science. A fireman holding a safety lamp, of the type invented by Sir Humphry Davy, to a coal face to test for explosive gas. With a safety lamp, the gas burns in a characteristic way, but cannot explode. (*See* pp. 5, 179.)

From *Gas and Flame*, issued by the Safety in Mines Research Board.

By permission of the Controller of H.M. Stationery Office.

the "Marquis" wheat was invented in Canada, vast regions were thrown open to profitable wheat-growing, and great numbers of men pushed forward to take advantage of the fact. Ought we to go on trying to find new wheats now that farmers cannot find a market for what they have? Will the improvements in the refrigeration of meat on board ship and the consequent increase in imports press still more hardly on our farmers? Can our growers find advantages to be taken of their home position, which may turn the scale in their favour? What a number of difficult problems present themselves!

Next to these old pieces of tubing are others shaped like the letter V; little pieces of platinum at the end of copper wires are inserted into both sides of the V. They are tubes which Faraday used when he worked out the laws of a process which most people know by the name of electro-plating. It cannot be denied that this is an extraordinarily useful business, and that it employs great numbers of men. We should be very sorry to be deprived of it. There are other things of interest in this window, each with its story to tell, but we must move on. So we come to the most dramatic of all the objects in the show: the famous ring of iron wound with copper wire which was the foundation of all electrical engineering. So much was said about it three years ago, when all the world was honouring the centenary of Faraday's discovery, that little need be said about it now. We will remind ourselves only of the vastness of our modern uses of electricity. It seems to me to be a very significant fact that the electrical industry, born so lately of our discoveries and inventions, should be so active,

should give so much employment, and be so much employed. To my mind, it fits in with the idea that we are all happier and better when we strike out continually on new lines Every good workman loves an occasional new tool, and goes to his work with fresh interest.

But now we must move on quickly. Here is a window showing, among other things, a row of little flasks, sealed up to keep the liquids which they contain from contact with the air. Sixty years ago John Tyndall filled them with broths or extracts of various kinds of meat and game He wished to show that these would keep indefinitely if pure themselves, and if the air in contact with them was pure also They look quite fresh still, with the exception of one or two. Tyndall insisted that in ordinary air there are minute living particles, which we now know as bacteria. Those who had argued for the spontaneous generation of life had not been careful enough. They had allowed air laden with bacteria to get into touch with their broths. It is interesting to note that these investigations impressed Tyndall with the value of pure air. He found that the air near Haslemere, at Hindhead, was very pure, and built himself a house there; and many followed his example.

And now in our mind's eyes a wide vista spreads itself before us, opened up by this and other pioneering investigations. We have learnt the tremendous importance of this invisible life to our national health, to our food, to agriculture: we recognize some bacteria as friends, some as enemies. Deadly epidemics have been stayed or prevented by such knowledge. Shall we wish we had been kept in ignorance? Have we allowed

populations to grow too fast by removing the plagues that thinned them? And especially have we kept alive many who would be better dead? We must try to make up our minds on these points, and all that Mr. Huxley has to tell us will be useful.

A few steps more and we must bring the little tour to an end Of all the objects left to be considered we must be content with two. Here is a little collection of apparatus used by the late Lord Rayleigh in his work on acoustics: metal discs of various forms, whistles of so high a pitch that very few, even of the youngest, ears can hear them. Rayleigh's work with that of others came into use during the War when apparatus had to be devised which would listen under water for the noises made by submarines, and on land would help to detect the whereabouts of aeroplanes and guns. Since then the importance of sound and its laws thrusts itself upon us more and more, in the long-neglected design of halls fit for speech and music, in the construction of telephones and of loudspeakers. The control of sound is a peculiarly interesting question just now, because so many complain of the torment of noise in town, and out of town, and of the want of privacy in the new piles of flats.

And in the last window of this corridor is the history of the vacuum flask which Dewar invented to keep his liquid air from boiling away. The first rough attempts are there, and in succession are the gradually improving patterns leading up to the present familiar form I do not think we should like to smash up all our vacuum flasks, either those of us who make use of them in daily life or those who find them invaluable in the laboratory and the factory. But it might, on reflection, be pos-

sible to find a reason why we should be better without them.

This little tour will, I hope, have served to show you scientific knowledge at its source, and have called to mind the wide use that the world makes of it. We have seen, too, how many puzzling questions arise even from this broad point of view. But we shall have to go further. A large part of that which is still left to be considered is concerned with the application of science to the construction of the machine We all know well that the machine can be both a blessing and a curse. It can pour out its products in a stream sufficient for all, and yet it can rob many of the opportunity to earn. Is it possible to control the application of science to the development of machinery? The growth of knowledge, like the rain, descends alike upon the just and upon the unjust; and it is as impossible to stay the former as it is to hinder the latter. A wise people conserves its water and directs it into useful channels Individual citizens may not use it wastefully or selfishly And certainly they may not use it to their neighbour's injury, they may not, for example, turn a destructive stream upon someone else's property. But there is no analogous control over the use of scientific results. Is any such control possible?

Pure science, that which I have referred to as long-distance science, is international At a scientific conference nationality disappears. It is when the results of science are incorporated into business and trade that trouble begins. To parody an old saying, when patents come in at the door peace flies out of the window. But can we avoid this competition as long as we are a trading and a manufacturing nation? And if we

cannot, what are we doing as a nation to incorporate our growing knowledge, to add to it and to use it? Sometimes it is said with a certain defiance that "What was good for our fathers is good enough for us." That is very likely to be true, but it would not be good enough for the fathers if they were still alive. The energy and the wit which made them into what they were would by now be making them into something else

Mr. Huxley visits the research laboratories of the universities, of the trade associations formed in connection with the Government, and of various firms, and tells us what he sees. It is well to get at the facts; we shall then be better able to judge where we are. We may not be all in agreement as to the need for the pursuit of knowledge in the satisfaction of our curiosity, in the exercise of our talents, in the enlargement of our minds. There are certainly differences among us as to how it should be used and controlled when we have got it. We all approve the use of it for mutual help. We probably deplore the use of it for mutual injury. We surely disagree as to the extent to which we may use it to fight each other economically. But we all agree in our satisfaction that Mr. Huxley has undertaken this mission.

CHAPTER II

RAISING THE ISSUES

In this chapter are treated some of the main questions that require investigation, in the form of a discussion between the author and Professor Levy

Levy. So, Huxley, I hear you are rushing round the country making a survey of scientific activity.

Huxley. Yes, Levy, I have started trying to find out something about the different ways and means by which scientific research is being carried on here and its results applied. So I have already been to Scotland and Wales, and shall go on for some time visiting various laboratories and research institutions. The idea is to attempt to discover how far science to-day is helping to cater for the needs of the people of this country.

H. L. Do you mean you propose to show how science is serving the needs of British industry?

J. H. No, that is only a fraction of what I had in mind. After all, science is helping Government Departments like the Post Office, and it is being used to improve the nation's health. Besides that, I want to see what is being done in regard to pure science.

H. L. I see. Of course, all these—and more—come within the ambit of science; but the question I was suggesting was whether in the main—historically, if you

like—the driving force of science is not its use for production, and whether all these other aspects are not really subsidiary to that

J. H. Well, I do not know that I have thought much about the problem along those lines. Perhaps we ought to clear the ground a bit and get down to fundamentals.

H. L. All right: let us begin by examining what this science is which you are going to study. I suggest that the proper way to approach that question is first, to examine what science has done in social life, its relation to man's needs, and the methods it has developed for handling the raw material of Nature. Secondly, if we wish to understand why science has taken on the complexion it has, we shall have to ask ourselves some questions about the nature of the forces that have directed scientific attention to certain fields, to the exclusion of others. For example, why so many scientists turn to the properties of dead matter and so few to social problems; why, for instance, we know so much about cold storage and so little about how the community is run.

J. H. Well, of course, those are aspects of the question. But I generally like to think of science as a body of knowledge. The knowledge is organized, and it is based on the scientific method. And the scientific method consists of testing your results by observation and experiment, and in publishing your facts and your procedure in full, so that others can check your conclusions.

This knowledge can, of course, generally be applied to controlling nature, but most scientists, I think, would say that there definitely is something that can be

called *pure science,* which has a momentum of its own and goes on growing irrespective of its applications.

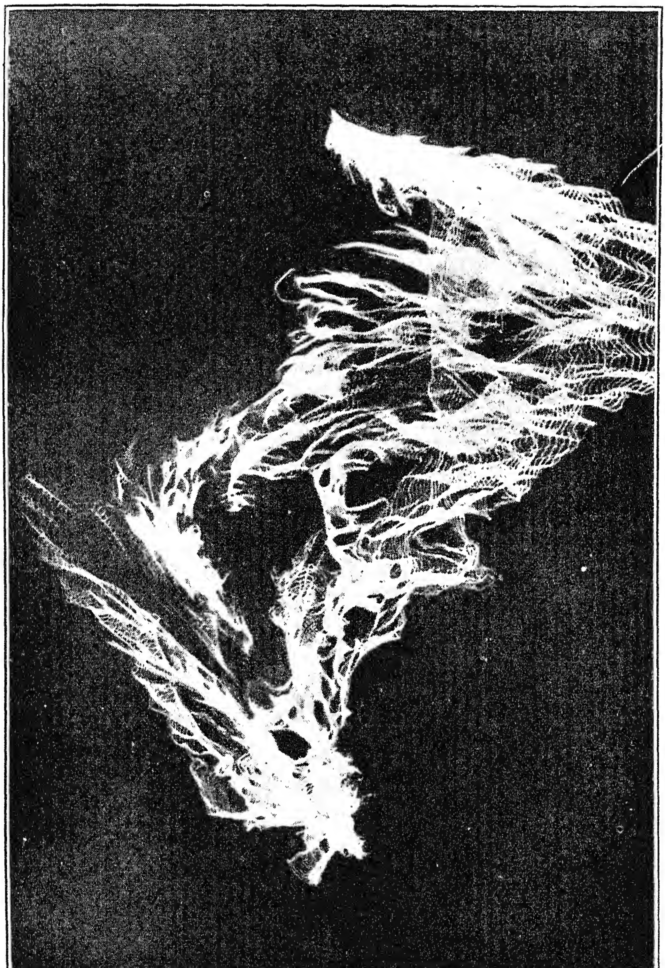
H. L. Well, Huxley, I think that to state things in this way is to lay a false emphasis on pure science. Can there be any essential division other than of degree between it and applied science? Surely they are interdependent, and differ only in their remoteness from application.

J. H. Well, what about Greek science, for instance, which had hardly any applications?

H. L. I was talking primarily of the vast developments in science during the past few hundred years. The Greek state was catered for by ample slave labour, and therefore there was no need for mechanization, for labour-saving devices. Thus the interests of the Greeks—at least, those who were not slaves—were those of a leisured class, and therefore their science was mainly philosophical in complexion. Whatever application there was, was mainly to war, and to the arts—like architecture.

J. H. Yes, I see that. I suppose that is also why Greek science differed so radically from modern science in having little experimental foundation, and why the ancient Greek scientists, unlike modern scientists with their detailed technical publications, seem not to have been interested in the methods by which they reached their results, but only in their conclusions. As a matter of history, I suppose it is fair to say that modern science began in earnest less than three hundred years ago with Francis Bacon, and his emphasis on the need for objective testing.

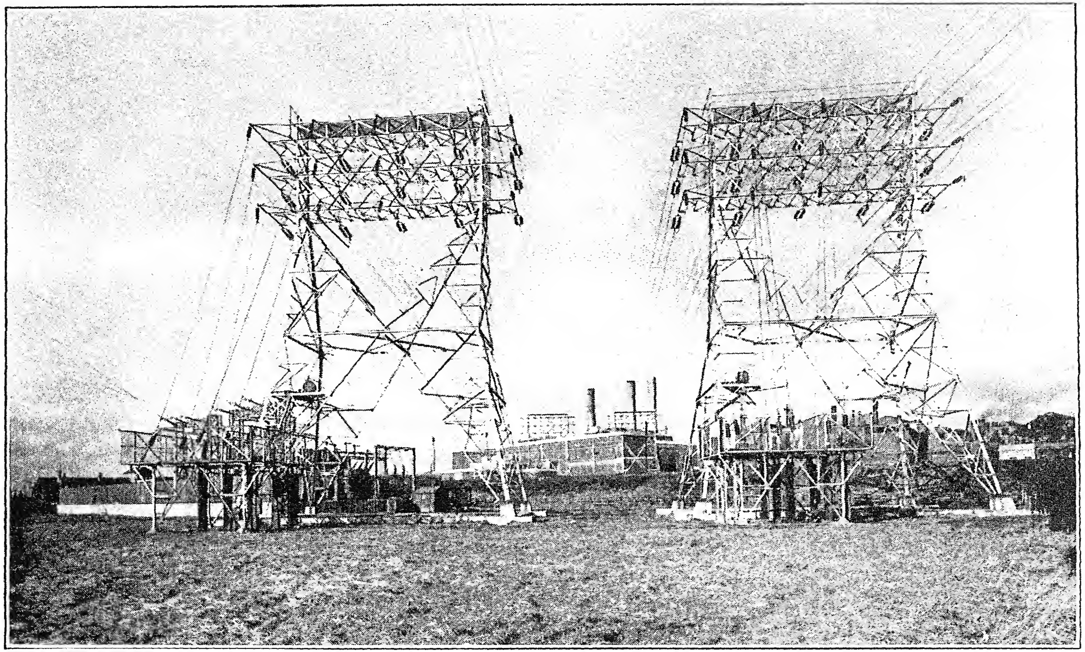
H. L. All right. But surely this underlines my earlier point, that science takes its complexion mainly



Basic science in the laboratory: a million-volt spark produced in the electrical section of the National Physical Laboratory at Teddington. (*See* p. 210.)

From *The National Physical Laboratory* (1933).

By permission of the Controller of H.M. Stationery Office.



The application of science to social needs: a power station of the electricity Grid. (*See* p. 210.)

By courtesy of the Central Electricity Board.

from the social and economic life of the times There was little experimenting among the Greeks, because there was little need for application, whereas at the time of Bacon social life had changed considerably, transport and navigation to distant parts of the earth had come in with commerce, crude slavery had all but passed away. All these changes were stimulating that deliberate and critical study of nature which we call experimental science.

J. H. That is all very reasonable. But what about pure science to-day? There are surely plenty of practical problems for science to deal with now, and yet we find scientists spending a great deal of time on very abstract and remote questions, like the quantum theory, the habits of deep-sea fish, the expanding universe, or the internal constitution of stars, that we can never hope to influence at all or to control in any way.

H. L. Ah, that arises, it seems to me, from the peculiar nature of modern conditions, where the scientific movement, unable to find an outlet for its accumulating energy—for its momentum, if you like,—in industrial practice, turns rather to more speculative fields. That, however, is another story. Anyhow, even these matters you mentioned are associated with others which themselves have applications. For instance, take the Quantum Theory. This has applications not very remote from the state of affairs inside the ordinary wireless valve. Scientific work interlocks from one end of the scale to the other.

J. H. Yes, I see your point. I can give you an interesting illustration of that sort of thing in my own field. Dr. Adrian of Cambridge has been making

remarkable discoveries about the way in which our nerves and brains work. But his researches were only made possible by using certain kinds of amplifiers, which in their turn would never have been developed if it had not been for their very practical use in wireless.

All the same, there are difficulties in your severely practical view. Surely a great deal of scientific work gets done just to satisfy the interest of the scientists who carry it out? And if so, is it not being carried out for its own sake, as an end in itself?

H. L Yes, to the individual scientist it appears so; it gratifies an individual desire and provides a personal satisfaction. So to him it appears *an end in itself.* That is, of course, a practical but a purely personal aspect The scientific work he does, however, is taken up by someone else, and so he has played his part in the movement we call science He has his personal interpretation of the small part he has played; but *we* have to see science in wider perspective: as a social affair fulfilling, however inadequately, certain social needs, or providing some of the machinery for their fulfilment.

J. H. That is still all right; but what about the keen amateur scientist—the amateur astronomer or insect-collector or bird-watcher? He surely is making his observations an end in themselves?

H. L. In that sense, yes That sort of work is satisfying a personal need, certainly. But just because it is so personal its scope is restricted.

J. H. It seems to me there are two things involved—the impulse of curiosity, which man shares with other animals such as the apes, and the direction in which

that impulse is used. You will not get good science of the purer kind unless the curiosity impulse is strongly developed.

H. L Yes, but the particular result depends on the direction, and that is determined primarily by social forces

J H. It depends on both, just as human achievement depends both on heredity and on environment. But, in spite of the large amount of shaping which the scientific impulse receives from social and economic forces, it remains as a plain fact, does it not, that the conclusions of science in a very real sense reach much beyond the limits of the social system which gave them birth. They are much more universal than any particular society or epoch, and lead to a structure of fact and idea which is accepted by all who are capable of dispassionately following the reasoning involved, irrespective of their race or nationality. Russian scientists did not reject the discoveries of Morgan and his colleagues on heredity because they came from "bourgeois" America: they used them in their own research. Nor does English or German science refuse to see the validity of all the discoveries now being made by "communist science" in Soviet Russia. Science has a pure aspect because it is in part the product of the impulse to discover for the sake of discovery. It also has a universal or general aspect because its very method makes it capable of being tested by anyone competent, and so its results are accepted by competent people irrespective of race, nationality, religion, or class. It also has a practical aspect because it is in part the product of the impulse to control nature for human ends, and a local social aspect because its

growth is stimulated and guided by the social and economic forces of the time.

H. L. It does not seem to me that science becomes "pure" because there are individual scientific workers whose personal motive in carrying through investigations is that they desire simply to extend the boundaries of knowledge. The existence of such a motive does not necessarily enable them to lift themselves outside their historic social epoch, but it may mean that they will concentrate their attention on problems more remote from direct application. Of course, the conclusions of science must reach beyond the limits of the social system that gave them birth, for the simple reason that science concerns itself with a study of the material physical world, and that physical world exists objectively and irrespective of particular social systems. Science, however, does not cease at discovery. It is also concerned with application, and the applications are to the systems of society in being—British, German, Russian, or American. Moreover, since scientists, like other workers, have to earn their living, it seems to me that to a large extent the demands of those who provide the money will, very broadly, determine the "spread" of scientific interest in the field of applied science. It is from there that the driving force is exerted on the scientific movement. I know of no scientist who is so free that he can study absolutely anything he likes, or who is not restricted in some way by limitations such as the cost of equipment. With most of what you have said, however, I agree, but I think it has to be seen in this setting.

J. H. Well, I think we might see how far we agree now, after all this argument. How will this do as a

formal definition? Science in the modern sense is a body of knowledge which has been tested by experiment. Historically it has grown as a result of several factors, which affect man both as an individual and as a social animal. These factors are . first, our need to exercise some control over the forces of nature; secondly, our impulses of manipulation, curiosity, and our urge to understand man's place in the universe, and thirdly, the pleasure we get out of the use of our faculties in the process of observing, understanding, and changing nature. Would you agree to that?

H. L. Yes, I think that will do, although you are still thinking of science primarily as a body of knowledge. But now, agreeing that science and the scientific movement have emerged out of the growing needs of society, we ought to study it as a movement, to examine what stress has been placed on the various aspects of it—for example, the purer as opposed to the more definitely applied. What, for example, settles how much money shall be devoted to scientific work in the Universities in comparison with severely technological work outside of them? Is there any deliberate study and control of the scientific movement as a whole, or does it just develop chaotically?

J. H. Of course, that is a very difficult question—so many factors are involved. For one thing, so much of the work done at the Universities, I quite agree, interlocks with practical applications that one can hardly draw a sharp line between the two fields.

H. L. Would you, then, agree that the Universities and other purely academic institutions are doing work essential to industry which industrialists do not or will not do for themselves? For example, Faraday's

electromagnetic discoveries and his investigations of the constitution of benzene, conducted at the Royal Institution, were ultimately accepted by industrialists, but the work was not initiated by them, fundamental as it was. It had to be done at an academic institution.

J H. That, I think, is certainly true. The industrialists of Faraday's day did not even see the possibility of applying it for quite a number of years Or we might take the researches on heredity begun by Mendel and carried on for a long time almost entirely in University laboratories, on more or less useless animals like flies and mice and shrimps. But they are now finding important and useful applications in plant and animal breeding.

In the present condition of world affairs, it looks definitely as if industry is on the whole unwilling, and apparently unable, either to provide the broad scientific background of research out of which new applications grow or to undertake large-scale and fundamental investigations which do not promise fairly immediate returns. On the whole, it is fair to say that the Universities provide the background, and Government institutions (like the National Physical Laboratory and other branches of the Department of Scientific and Industrial Research) carry out the long-term investigations.

H. L. So you agree that Universities, whatever else they are doing, are unconsciously playing their part in assisting industrialists to carry on their business?

J. H. Yes, that is so. Of course, the Universities, like any other social institutions, cannot help doing something to serve the ends of the society in which they have grown up. But helping industrialists is only one

side even of this aspect of Universities They may help to cheapen production so that prices can be brought down, and also help to stimulate new inventions, and so to cater for needs that have hitherto not been satisfied.

H L. Yes, science has been used in this way, but even this analysis of yours is surely incomplete. There is a real distinction between two possible ways in which science operates. First, science may serve certain social and individual needs directly, by stimulating our intellectual and philosophical interest It may expose the false basis to many of the beliefs we have inherited from the past, and provide us with assured knowledge on which to reconstruct our view of life and of society. It assists, in fact, to sharpen our critical sense and to enlarge our outlook Secondly, however, science comes to society indirectly. It may be used by those who have made it their business to cater for more immediate practical social needs Before the results of science get to society by this route, it has to be worth these people's while to use it. For the moment, however, we will leave that. Meanwhile I would like to hear more of what you intend to do in your survey.

J. H. Well, as I said at the beginning, I shall be trying to find out what science is doing in this country to cater for its social needs. And the way I propose to divide up the field is roughly this. I shall take obvious needs like food, clothing, building and shelter, transport, and health, and see what science is doing to help there. Then there is the relation of science to industry in general—where the funds come from, and how the research is planned and controlled; there is the assistance that scientists are giving in preparing

for war, and the question of what the psychological side of science is doing to ease the mental tensions set up by society. And, of course, there will be something to say as to the scope of what we have just been discussing: namely, science for its own sake—what is being done in the way of pure science in the Universities, and of amateur science carried on as a hobby.

H L Then does there not still remain the question of how science is actually organized to do all this work?

J. H. Yes, I was coming to that You have only got to think for a moment to realize that the work is carried out in the most varied ways Some is done in laboratories attached to private firms, some in Universities, some in Government institutions, some through scientific and other societies, some in research laboratories financed by industries, some with the help of international organizations I shall try to see examples of all these types. In particular, I want to see if I can find out something about the imperfections and gaps in our scientific organization.

H. L. Well, this survey of yours is going to be a big job, isn't it?

J. H. Yes, indeed—such a big job that I shall only be able to deal with a small part of each field. All the same, I think I shall be able to make a survey which will give a useful general picture of the whole subject, and will bring out the co-ordination of all the scattered work, as far as it is co-ordinated at all. And at the end I suppose you will want to come back and ask me some more of these troublesome questions!

H. L. Well, if I ask you troublesome questions, it is because science must needs be associated with trouble-

some things But I should really like you to discover during your survey the answers to one or two difficulties I have You know how glibly people talk about science being open, published for all, and working for the benefit of humanity. I wonder if you are not likely to find that a good deal of research for private firms is conducted in secrecy, so that the scientific knowledge is kept within the factory walls and used for private profit only, while these same firms are busy, as you have agreed, in absorbing the fundamental scientific work which is done outside their walls in public institutions. And then again, I wonder how much research is conducted primarily for national purposes—information and ideas which this country must keep to itself in order that British industrialists, and British War Departments too, may compete successfully against the foreigner. This may all sound very nasty, but I am raising the question because, if what I am hinting at is true, we must give up all this clap-trap about science *always* being the benefactor of humanity at large and international in all its aspects.

J. H. Well, that grows naturally out of the programme I have just outlined.

H. L. Then there is another point. You and I, Huxley, seem to be assuming that industry can absorb as much science as scientists can produce. I wonder how far you may find science running to waste. What I mean is just this. The scientific movement measures success in the application of its work when it produces the machinery for plenty—when, for instance, it makes four ears of corn grow where one grew before—but nowadays we are beginning to realize that success in industry often demands scarcity and

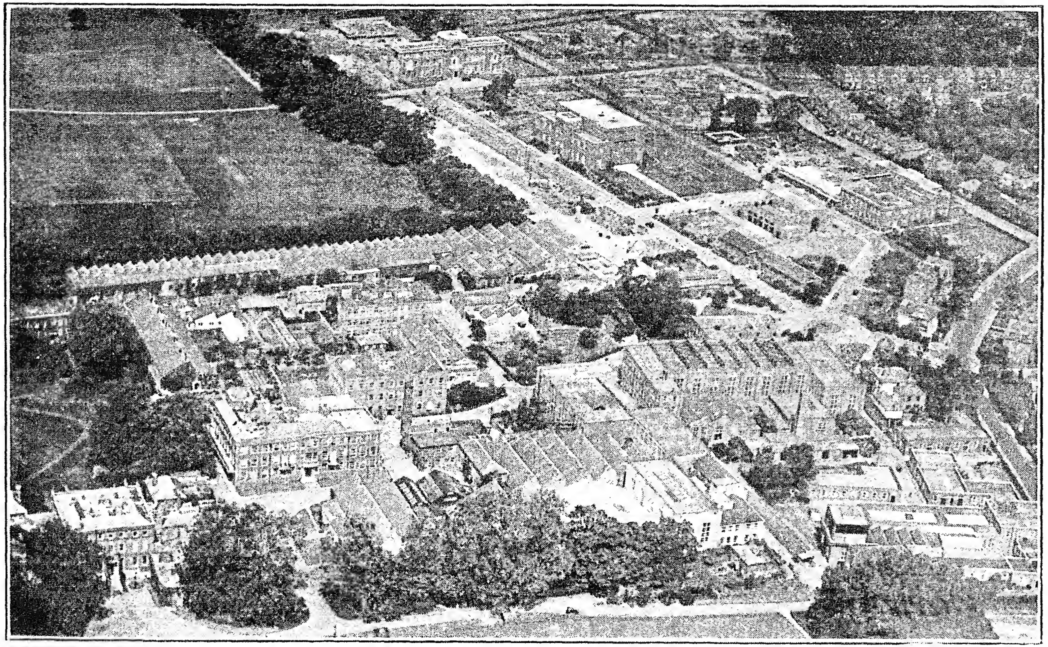
high prices. You talk about scientific applications to agriculture, but at the same time politicians and industry are restricting production, and that, mark you, side by side with unsatisfied needs and even starvation all over the world. Does it not look as if those who are to supply the needs of the community are in a cleft stick? They dare only use science in a very restricted form.

J. H. Let me get this clear. Are you implying that science is responsible for over-production: in fact, that the world is suffering from too much science?

H. L. Oh, no. That is the wrong way to put it. There is plenty of scope for science. But just where science is most needed, the present order of society is incapable of absorbing it. Agriculture is a case in point, but there are plenty of other examples.

J. H. Naturally, that is important, and I shall certainly keep an eye open for examples of that sort. But meanwhile we live in a capitalist world, and science and scientists have to take the organization of industry as they find it.

H. L. Yes, naturally. But I think it is important we should see the contradiction between some of the ideals that the ordinary layman and the scientist have about science and the way it actually functions Take this question of nationalism, for example. The Department of Scientific and Industrial Research is a Government organization which exists definitely to promote British industry as against the industries of other countries I am not complaining about that—it does its job very efficiently indeed—but I think it is important that we should see that science is being used for this nationalist purpose, and we must not



Arthur W. Hobart.

The headquarters of governmental research in physical science: the National Physical Laboratory, Teddington. An aerial view, 1932.

Gas masks are useful in peace as well as war. A new type of gas mask for mine rescue work designed as the result of research by the Safety in Mines Research Board: the air is breathed through a canister containing manganese dioxide and copper oxide to protect rescue workers from carbon monoxide and other poisonous gases formed after an explosion. With this type of mask, the rescuers need not carry oxygen cylinders to breathe with. (*See* pp. 159, 179.)

From *Safety in Coal Mines : Some Problems of Research.*

By permission of the Controller of H.M. Stationery Office.

pretend that it is not, by proclaiming that science is international.

J. H. That, too, I suppose, is inevitable, so long as the world is organized into national sovereign states. And, of course, this has a further consequence—namely, that every nation has to devote a good deal of its scientific energy to research which is to be of use in war.

H. L. I see. So that science here plays a vital part in a consequence of nationalism—namely, war. Are you, then, also proposing to look into this side of scientific research? That *will* be interesting, if you can discover much about it.

J. H Yes, naturally that cannot be left out. But meanwhile do not let us forget that research which is undertaken or financed primarily for war needs may have results that are useful for all sorts of peace-time purposes. Aviation would never have developed as rapidly as it has if it had not been for the Great War. Research in the optical glass industry has a background of war-time ends; but it gives us better field-glasses and camera lenses and microscopes in times of peace Gas-masks for use in coal-mines and industrial occupations have been improved owing to research to protect soldiers and civilians from poison gas used for military ends. Or again, the need of understanding and curing the thousands of so-called "shell-shock" cases during the War was responsible for a remarkable advance in psychological science, which is now being of the greatest service in dealing with peace-time disorders.

H. L. Well, it is not necessary to justify war that way. Actually, war follows naturally out of the struggle for markets, and I anticipate that you will

see how science is being used to intensify the one and prepare for the other But let us pass to a less unsavoury subject, from the destruction of human life to its conservation. Do you propose to see whether science is being used to its full extent for the health of the community? Is it the case that research into, say, industrial fatigue is conducted in the interests of the workers, or primarily for increased efficiency of production?

J. H. That is going to be rather a difficult question to answer. But I expect to have something to say on the more general problem of whether scientific knowledge, in this field of the nation's health, is really being used to the fullest possible extent, and as a matter of fact I can tell you beforehand that it is not.

H. L. I guessed as much. And now, Huxley, let us hear a little more about the international aspect of science. It is peculiar that it should have this aspect, considering the fact that, as we have seen, it is used so much for national purposes. There would appear here surely to be two conflicting currents at work.

J. H. Yes, that arises from what I said before. There is in science something that inevitably is universal, because it springs from the fundamental human impulse of curiosity, of wanting to know for the sake of knowing. But there is also the desire to control events and things for use and profit, and this gets tangled up with industry and nationalism, while the other is always tending to transcend such limitations.

H. L. Well, enough of theory—what about international science in practice?

J. H. Oh, there are, of course, plenty of examples ready to hand. For instance, one of the most efficient

remedies for African sleeping sickness is a drug called Bayer 205. This was discovered in a German research laboratory, but finds its chief use in British, French, and Belgian colonies. Then there is the famous example of the synthetic aniline dyes which scientists produce out of coal-tar. The original discovery of the methods was made in England, but Germany was the only country to make commercial application of them for many years afterwards

H. L. Yes, that is so But the reason for that is interesting We must remember that Britain at that period held a well-assured position in the world markets, while German manufacturers were struggling to secure a foothold. Thus they were on the alert to use science at once for that purpose, backed by the German State. Thus, in Germany, under the drive of her industrial needs, industrial research institutions came into existence earlier than here, where they were largely stimulated by the Great War. So when you say that science is international, is it not the case that it is simply those elements of science very remote from industrial application that are international? That is, of course, a great deal, as scientific journals testify—three-quarters of a million scientific and technical contributions every year!

J. H. Yes; but in spite of all you say about nationalism in science, I do not think many laymen realize the extent of the international side of science—the interchange of brains from one country to another by means of research fellowships, exchange professorships, and so on; the congresses at which scientists of all nations take part; the way in which a discovery made in one country is taken up almost at once in

another. What *is* clear, I think, is that science is trying to work on a lot of different levels, so to speak—sometimes in the service of a single firm, sometimes in that of a single industry, or again in the service of a single nation or empire, and finally on the international level, where discoveries are announced freely, and fully published so as to be available to humanity at large.

H. L. So to that extent science, like the scramble for trade, is riven by conflicting tendencies—international publication, national secrecy, trade secrecy, the ideals of scientific men.

J. H. Yes, I am afraid that is so And I shall try, if I can, to lay my finger on particular cases where competitive secrecy is interfering with scientific ideals.

H. L. Do you propose also examining where the gaps lie in the field of scientific study?

J. H. What exactly are you thinking of?

H. L Well, if one of the main driving forces that determines the direction of research—I do not say it is the only one—is this need for help from science on the part of those who undertake production, then the scope of scientific inquiry is likely to be affected by this fact. For example, do scientists know why production has gone down to such a low ebb, in spite of the marvellous achievements of science? Before the War, it has been argued, we had crises associated with over-production, and now at the present moment, in spite of the refinements of science in production, we have a world-wide crisis, with actual under-production and widespread restriction of output. The Economic Conference brought that out, at any rate. Have scientists reached agreement on that issue, or do you

think it is not even a suitable subject for scientific study?

J. H. Why, certainly, any subject is capable of being examined by the scientific method. For instance, most industrial research is aimed at making production more efficient. But why should not the State, through the Department of Scientific and Industrial Research, set going a really scientific investigation on the problem of how to stimulate consumption? Consumption is just as much a problem for scientific research as is production Only, owing to our economic system, it has been nobody's business to apply scientific ideas to it.

H. L. Yes, but I should like to see added to that problem this: should it be found possible to discover the underlying causes of all these contradictions, is it likely that those who have the power to act so as to resolve them, will agree to taking the necessary steps? It may hit them badly, you know. Even scientists themselves are not likely to be unbiased in such matters

J. H. I quite agree. It means that we must regard society itself as a proper object for scientific treatment, which is a rather revolutionary idea. At the moment, for instance, educational policy has no scientific basis, but is determined by all sorts of unscientific motives, such as political pressure, religious feeling, and mere tradition. And then there is the point you make about general bias. Now that is something so unconscious with most people that I do not think they are even aware of it. Even scientists, with a few exceptions, are not aware of the fact that they are biased, and would be indignant if you told

them that they were. And of course when people get indignant about anything, it is generally a sign that they have not thought scientifically on the subject. The scientific movement is an outgrowth of society, and cannot help being influenced by the form of the society from which it springs.

H. L Yes. For that reason the more fundamental social problems have been kept in scientific darkness: the light has not been turned on problems of social structure, causes of war, the social bias in education, the basis of religious belief, the rationale of sex, and so on. In fact, our form of society has rendered them almost taboo to anything that could be called scientific treatment

J. H. Yes, what we need now, it seems to me, is a change of outlook—a feeling that science *should* be asked to help in tackling such problems, that we ought to arrange for more of the best brains to go into the study of society, that the Government ought to organize research on social subjects as it already does on industry and agriculture and health. That would be a revolutionary change.

H. L. It would indeed. But you may recollect that you agreed that institutions reflected the bias of the society in which they developed. Government and the State are such institutions: they tacitly assume the permanence and the structure of present-day society, and therefore their use of science necessarily also reflects their bias.

J. H. Yes, that is true enough; but you must have a beginning somewhere, and, whatever you say, a change of the sort I suggested *would* be revolutionary. What is more, there are signs that at last the scientists

themselves are coming alive to the existence and importance of this problem. For instance, the British Association has just decided to devote a large part of its time at this year's meeting in Aberdeen to considering the social bearings of scientific work Do you not think that is an interesting symptom?

H. L. Well, it is clearly a very important matter and one that strikes radically at the whole problem of the use of science in society It is as critical for science as it is for society.

J. H. Yes, I agree But meanwhile I shall have to get on with my survey, and I think we must leave this question to be dealt with in our final discussion, with all the facts in front of us It may turn out that this is, after all, the most important social need for which science could possibly cater.

H. L. Well, it is not becoming for scientific men to talk of luck, but you will certainly need it! Good-bye.

CHAPTER III

SCIENCE AND FOOD

FOOD is not merely a social need: it is a biological one. All the same, as society grows in size and complexity, the needs connected with food get more varied and more elaborated. To-day a large portion of the population live in big towns, so that the transport and distribution of everyday articles of diet, especially perishable ones like milk or fish, have become a serious problem. To-day, too, people want food from all over the world—think of West Indian bananas, New Zealand mutton, Californian grape-fruit, Argentine beef. And this involves even bigger problems of transport and distribution. Then, with the growth of transport facilities, the natural tendency has been for food to be grown intensively, often on an enormous scale—as on the Canadian wheat-farms or the South American cattle-ranches—in the regions of the world best suited to its production, and then exported. Food-production is now largely a capitalist business enterprise carried out on a world-scale. And this, of course, has sharpened competition. The result is that there is a premium on certain kinds of improvements at every stage of the business—the making of new varieties of food-plants and food-animals, the technique of growing and rearing them, their storage and preservation in transit; and at every point science has been called in to help in making these improvements.

In a single chapter I obviously cannot cover all these applications of science to this great problem of our food. So I shall take one or two threads and see where they lead.

My story ought to have begun with a visit to the Abbé Mendel's garden in the monastery at Brno, in Czechoslovakia. But Mendel died before I was born, and even if I had been privileged to visit him and see his work, I could never have foreseen all that has grown out of it. So I will begin with the School of Agriculture in Cambridge, where I called on Sir Rowland Biffen.

Mendel's work was published in 1865, and lay unnoticed between the covers of a rather obscure scientific journal for thirty-five years When it was unearthed again in 1900, it was immediately seen to be of outstanding importance to the science of heredity. Among the men who saw its importance was William Bateson of Cambridge, and it was through his insight and enthusiasm that Cambridge soon became a centre for research in this new branch of science.

The essence of Mendelism is that hereditary characters are determined by definite unit particles which are handed on from parent to offspring in the reproductive cells, and that, owing to the microscopic machinery of those cells, the hereditary units can be shuffled and re-dealt in new ways. This is quite contrary to the older ideas of heredity, which usually assumed that the characters of the parents became permanently blended in the offspring, more or less as coloured ink blends with water. Mendelism showed that there was no blending, but that, by means of properly-planned crosses, the various characters of different races can be taken to bits, so to speak, and

reassembled almost at will in all kinds of new and pure-breeding combinations

For obvious practical reasons of space and time, most of the early work on this new branch of science was done on small and, if possible, quick-breeding species—mice, primroses, flies, sweet peas, and the like—irrespective of their usefulness or uselessness to man. But soon it became clear that Mendel's laws were general, and that they applied to every variety of character in every kind of animal and plant; and then, naturally, scientists began to try to apply their knowledge to practical ends.

Thus Biffen's very practical work grew naturally out of the pioneer studies of Mendel and Bateson. If they were right, then it should be possible to build up new varieties of plants and animals by deliberate crosses, instead of confining yourself to slow selection—just as modern chemistry deliberately makes new substances by basing itself on the atomic theory, instead of mixing things in hit-or-miss fashion in a test-tube. This is what Biffen set himself to do with wheat.

Let me take one example of his work. He aimed at combining resistance to rust disease, which he found in an otherwise poor strain of wheat, with the high yield of one of the best cropping strains. So he crossed the two:—and the offspring were all susceptible to disease! This would have been discouraging to the older breeders—but not to a Mendelian, who knows that characters can be masked for a generation, but can still be bred out pure in later generations. In his crosses he introduced also the character of "hard" grain, rich in gluten, which the millers asked for, and

strong straw to prevent the plants from being too easily "laid" by storms, and succeeded in combining the characters he wanted after several generations of planned crossing and selection.

The two main strains he manufactured thus were called Little Joss and Yeoman. Although not put on the market till 1912 and 1917 respectively, by 1927 they occupied about a third of all the world's wheat-lands.

However, Yeoman does not suit all soils, especially clays and light sands; and now one of Biffen's chief aims is to make new types of Yeoman—by breeding in new features from other strains—which will suit every kind of wheat land in Britain. It is on this problem that he is mainly busy. Besides that, he is trying to manufacture a spring wheat suitable for this country. Spring wheats are not necessary with our mild winters; but the introduction of sugar-beet, which is not harvested until November or December, has made it desirable to have a spring wheat to put on land that has been under beet the previous year.

I shall come back to Biffen and his wheats in a minute; but first let me take you to Professor Crew's Department at Edinburgh, which is designed to do for the breeding of animals what Sir Rowland Biffen's Institute aims to do for that of plants. I asked Crew what he thought were the most important practical results that his laboratory had achieved, and he answered, Bull-dog calves, for one thing, and the inheritance of milk-production for another. Bull-dog calves are a form of monstrosity which occurred with increasing frequency in the Dexter breed of cattle: they sometimes occurred to the tune of 20 or 25 per

cent. of all births, and some breeders were giving up their herds. Crew undertook to analyse the matter on Mendelian principles. He showed that you were bound to expect a high percentage of these monstrosities if you followed certain principles of breeding. What is more, he showed that if you followed certain other principles, you would no longer get any "bull-dogs" born.

The investigation on milk-production began with an examination of all the herd-books which the Department could get from breeders—a task which obviously only a big central institution could undertake. The milk records of thousands of cows were studied, and also their pedigrees. This showed, as clearly as any paper analysis without actual breeding experiments can show, that the tendency to high milk-production was due largely to what scientists call sex-linked inheritance, which is a special case of Mendelian inheritance. A sex-linked factor means something which a father transmits to all his daughters, but to none of his sons. A male, on the other hand, can only receive it from his mother. A well-known example from human beings is excessive bleeding or hæmophilia—the disease which the Russian Tsarevitch had. He got the hereditary factor for bleeding through his mother, and if he had lived and married, could only have passed it on through his daughters.

Most hereditary factors, of course, are transmitted equally from father or mother to all offspring of either sex. You will readily see that if a sex-linked factor enters into milk-production, breeders must use quite a different system of breeding from the ordinary. For instance, if you find a bull which sires a large number

of high-yielding cows, instead of keeping his sons to breed from, as you would naturally expect, you must reject them all—for none of them will have inherited the father's good qualities

What Crew would like to do is to test this out by actual experiment; but this would take years and be pretty costly, and at the moment he cannot get the money for such an experiment However, it is clear, I think, that he is on the track of something which could put up the average milk-yield of the cows of this country by anything from 20 to 40 or perhaps even 50 per cent. And the work which first gave us our understanding of sex-linked factors and enabled Crew to spot one when he saw its results in the herd-books, was carried out at Cambridge University on moths and at Columbia University on flies

Now let us go back to Biffen and his wheats. It is not enough to breed new varieties which seem all right on the experimental plot. They must be tested out under commercial conditions before they can be safely recommended to farmers. Biffen's own department cannot very well do this, and as a matter of fact the business is entrusted to the National Institute of Agricultural Botany.

Testing is just as important in its way as breeding, for each variety will behave differently in different conditions of soils and climate; and the Institute, with its six testing stations in different parts of the country, helps with this. It would be a good thing if there were more stations, covering the country still more thoroughly, but meanwhile the Institute supplies this necessary link in a pretty adequate way.

Then we must not forget the soil. There are a few

soils which are rich enough to dispense with chemical treatment, but with most soils you must put fertilizer on if the plant is to take out all it needs for optimum growth. The fundamentals of this branch of science are studied at the big Experimental Station at Rothamsted, directed by Sir John Russell, and many detailed soil problems are being worked out at the Experimental Farm belonging to Imperial Chemical Industries at Jealott's Hill.

I have not space to say much about this work, except that it is extremely important. It is only by careful studies, year after year, that we can find out how to bring land to its full yielding capacity and keep it there. And our present knowledge, if properly applied, would make it possible to bring off much bigger crops, especially with plants other than wheat,—such as oats or potatoes; and also with grass. But grass is animal food, not human food, and that brings me back to the question of how science can help with live-stock raising.

With regard to animals, the problem is more complicated than with plants, because there is an extra link in it—namely, the plants which the animals eat. Let us look at some of the points that arise. You may have the most wonderful breed of cattle or sheep in the world; but if you put them on poor pasture they will not do well. In fact, on really poor pasture they will do a good deal worse than much inferior stock, because to live and grow at all they need more and better food than the mediocre beasts. The pasture, in its turn, may be poor because it consists of poor kinds of grasses, or because it is growing on soil which is deficient in some important substance, like iron, or lime, or phos-

phorus. Further, the soil may be naturally deficient in the substance—for instance, there are big areas of the middle west of America where (owing to the ice-sheets of the glacial period) there is practically no iodine in the soil, and therefore human beings are unusually prone to develop goitre, and pigs are often born hairless and soon die. Or man may have caused the deficiency by constantly taking stuff out of the soil in the shape of the lime and phosphorus in the bones and meat of his animals, the iron in their blood, and so on, and never putting any back in the shape of fertilizer.

Two splendid Institutions I visited are especially concerned with these problems—the Welsh Plant-breeding Station at Aberystwyth and the Rowett Institute for the Study of Animal Nutrition at Aberdeen, both of them largely financed from State funds. Let me begin with the latter. From its start in 1922 the work here has been directed by Dr. John Orr, and has had the general purpose of finding out the relation between diet and disease, both in animals and in men. The researches started on these lines have not only revealed how to cure a number of obvious diseases, but have also shown that many animals and people who could never be classified as diseased are really suffering from slight deficiencies of diet, and that their health and vigour can be increased—often startlingly increased—if the diet is corrected. So that, instead of the rather negative idea of remedying obvious disease, the positive aim of promoting health through diet is gradually becoming dominant in the Institute.

I will only give one main sample of the work done here—the kind of laborious work which obviously can be undertaken only by a national institution with a

long-term policy and regular funds at its disposal. It concerned the nature of the diet afforded by different pastures to the live-stock of this island. To start with, a pasture survey was made. Samples of herbage from nearly 400 different localities were taken and carefully analysed chemically. One thing that early emerged was that almost any pasture, even the best-looking, could be improved both in the quantity and quality of its yield by adding the proper fertilizers. The next and perhaps more important point was that the great bulk of the hill pastures, which occupy such enormous tracts of our country, especially in Scotland and Wales, were badly below standard in regard to the amount of lime and phosphorus in the herbage they grow; and further, that this lack of the minerals necessary for bone-growth and for health in the animals pastured on them was almost always linked up with a deficiency in the nitrogen needed to build up flesh.

It was further pretty clear that, in general, low mineral content of the pastures went hand in hand with a high incidence of disease in the stock—mostly sheep—which grazed them; but to get accurate information on this, the Institute found it necessary to buy a farm of its own in Argyllshire, where careful experiment has been going on for nearly four years. This farm, in the mineral content of its herbage, is near the average of hill pastures. The experiments have shown that sheep on this farm not only did not get enough lime and phosphorus for healthy growth at any time of the year, but in the winter months were not getting enough sheer nourishment, as measured in the energy-units that physiologists call calories. In winter-time, to get full health and reasonable growth, it was necessary to

supplement the herbage with extra nutriment such as maize, and also extra minerals—or else to treat the soil beforehand with a fertilizer which would supply the deficiencies.

Further, it appears not only that a large area of the Scottish hill pasture is deficient in lime and other vital substances, but also that the deficiency has been getting steadily worse for the last fifty years or so. It seems clear that by a proper use of mineral fertilizers on the pastures, or by extra mineral-containing rations for the stock, the carrying capacity of hill pastures could be at least doubled—that man could make two sheep grow where only one grew before.

As a startling example of what proper feeding and careful management can do, I might mention that this year a cow at the Institute was made to rear no fewer than eleven calves in a single milk-period, in place of the two to four which is the usual number!

But before mentioning any more of the thoughts which come into one's head about the Rowett Institute's work, I would like to tell you something of what I saw at Aberystwyth under the guidance of its director, Professor Stapledon.

Professor Stapledon is an enthusiast about pasture plants in general and grasses in particular. I should imagine that he knows more about grasses and clovers than any other man in the world. I have not the time to do more than just mention the special bits of research that are going on at his Institute: an experiment with red clover involving half a million artificial crosses between different strains; work which is aimed at providing a new type of white clover better than the ordinary Dutch strain; breeding and selection experi-

ments with oats and different kinds of grasses. These last, by the way, have an interest of a general kind. Most researches of the sort set out to breed a variety which will give bigger yield or better growth in the most favourable conditions. But Stapledon, with the Welsh hills all round him, has his eye on the uplands, and his work is to select for unfavourable conditions—to make it possible for a richer kind of grass to grow in place of the usual moorland bents

But the most obviously exciting work is going on high up in the mountains. Long years of careful research on a comparatively small scale had convinced Stapledon that he could change the whole character of the hill vegetation for the better. Last year Sir Julien Cahn gave a considerable sum of money to put these ideas to the test on a large scale. With this money Stapledon purchased two tracts of land, one between 900 and 1300 feet up, another bigger one above the 1500-foot level. Both are just rough mountain pasture, yielding only a scanty nourishment to sheep even in summer. In winter the flocks from such areas have to be sent down and boarded out at so much a head on the pastures of lowland farms.

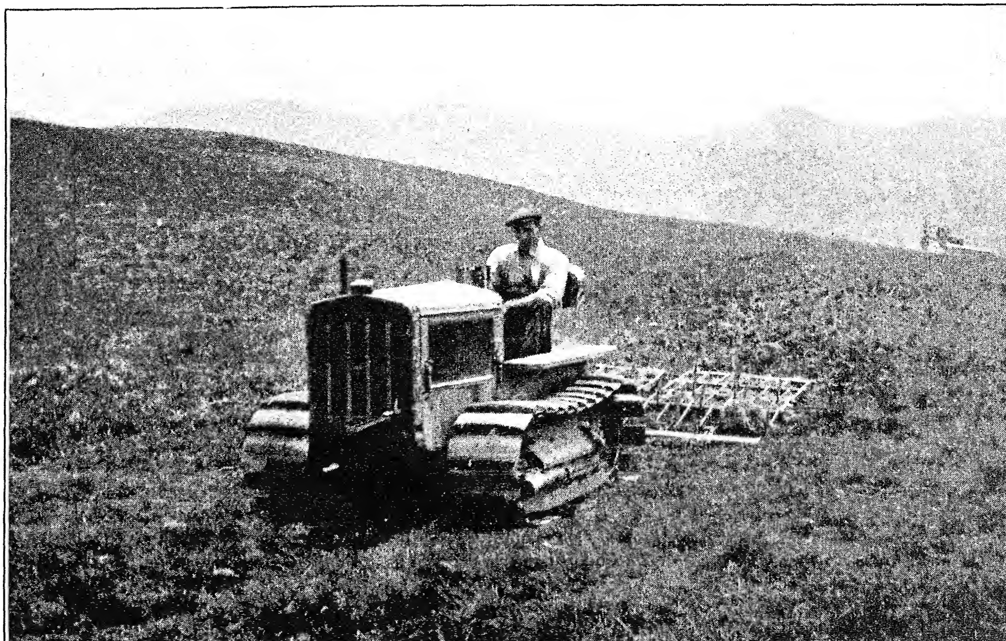
At the time of my visit at the end of September, the upland pastures were all turning ashen brown. Here and there, however, areas of summery green showed in the autumnal landscape. These were patches which Stapledon had treated according to his methods only a short six months before. They were covered with typical lowland grasses, which continue leafing much later than the types adapted to the bleak moorlands, and with a good proportion of clover.

Briefly, Stapledon has discovered that practically

Science and grass. A breeding nursery for selected strains of the Slender Wheat-Grass (*Agropyron tenerum*) in Western Canada. Notice the different types of plant in different rows. Similar nurseries are used at Aberystwyth. (*See* p. 43.)

From *Bulletin No. 7*.

By courtesy of the Imperial Bureau of Plant Genetics : Herbage Plants.



Turning rough mountain moorland into rich pasture. The first step—breaking up the existing surface. Photograph taken at 1200 feet above sea-level. (*See* p. 44.)

By courtesy of Professor R. G. Stapledon, Welsh Plant Breeding Station, Aberystwyth.

any hillside, at least up to the 2000-foot level, can be turned into pasture of lowland type by combining three procedures. The first is to get rid of the existing vegetation and to break up the soil; the second is to sow with the right mixture of grass and clover seeds, and the third is to supply the right blend of mineral fertilizers. Once this is done, proper grazing, with the occasional addition of fertilizer, will keep the pastures in condition.

Each of these three procedures has its long background of scientific and technical research. The first would be impossible without the development of the caterpillar tractor in the last ten years or so, to pull agricultural implements over otherwise inaccessible hillsides The right kind of tractors are already available ; but the right kind of implements is now the practical core of the problem. Ploughing would do, but is expensive anyhow, and the ploughshares often get broken on stones. Harrowing is another method; scraping, as for aerodrome surfaces or road-grading, another. Up in one corner of the moor is a collection of different types of implements that are being tried out. Perhaps a special one will have to be designed. But the finding of the right method here is now merely a matter of time and experiment.

Then there is the second procedure—of sowing the right seed mixture. The background to this is long experience, and also years of rigorous selection, by which Stapledon has manufactured types of lowland grasses which will stand up to hill conditions. And back of the third procedure—of supplying the right fertilizer—is nearly a century of experiment, beginning with the pioneer work of Lawes and Gilbert at Rotham-

sted in the early Victorian era. None of the procedures alone, or in couples, will do. All three are needed to establish the richer and more lasting pasture.

The lowland type of pasture thus established has all sorts of advantages. For one thing, it is more nutritious in itself; and, perhaps more important, it begins providing nutriment much earlier in the year and goes on providing it much longer. With such pastures available, the hill farmers would be able to graze many more sheep on the same land, and to keep them all the year round, instead of incurring the trouble and expense of boarding them out in the lowlands in winter. And there would be other advantages concerned with rearing fat lambs for sale at the best time for the market.

When you consider that nearly a quarter of the area of Great Britain consists of mountain and rough hill grazings, you will realize what a staggering change could be made by putting the results of these researches into practice. Even if the results were only applied up to 1500 feet, the change would be enormous.

And now I ought to say something as to the general ideas which I got from what I have seen. In the first place, the fundamental research is, without doubt, well organized and ably directed In plant and animal breeding, grass research, animal nutrition, soil science, fisheries, food storage, the study of the animal and plant enemies and parasites of crops, our British laboratories, such as those at Cambridge, Edinburgh, Aberystwyth, Aberdeen, Hull, Rothamsted, South Kensington, Jealott's Hill, backed up by the agricultural colleges and the University departments concerned with agriculture, are doing work of outstanding quality—original and vitally important.

But practically all the research men I have talked to showed an interesting mixture of optimism and pessimism. They all knew the scientific importance of their own work, and were convinced of its possible value for practice; several of them said to me that a doubling of the present amount of food grown in this country was not only perfectly possible, but a modest estimate of what could be achieved by applying the scientific knowledge which exists That, by the way, would make these islands self-supporting in regard to most foodstuffs (though not wheat)

But in contrast with this optimism as to possibilities was a certain pessimism as to actualities What is the good of doubling the number of sheep in the country if sheep prices may fall so low as to wipe out any reasonable profit to the farmer? What is the good of inventing new brands of wheat that will make it possible to grow more bushels of wheat to the acre or to push wheat cultivation nearer the pole, if the world's wheat-producers have on their hands vast surpluses they cannot dispose of profitably and are clamouring for a restriction of output and cultivation? What is the good of inventing new methods of cold storage which enable ships to ransack the recesses of the Arctic Ocean for fish, if a large proportion of the annual catch is thrown away or disposed of for manure?

Then, of course, there is the conflict between home and empire. What about New Zealand mutton and Australian beef if we double our own live-stock, or Canadian wheat and apples if we increase the home output? And there still remains the problem of the balance between agriculture and industry. If we are to go on exporting coal and steel and machinery and

motor-cars to other countries, they must be paid for by our taking something in exchange from those countries: foodstuffs are one of the biggest items in that balance-sheet

Then there are the conflicts of interests at home There is the interest of the breeder of pedigree cattle of a certain breed against the general livestock interest; that of the seedsman as against the farmer; of the wool merchant against the sheep-breeder; of the middle-man as against the producer and the consumer—one could go on almost indefinitely!

The outlook, mind you, is not all black. Much of the scientific results could be applied to-morrow to bring down cost for the farmers, and so make it possible for many more of them to make a decent assured profit, instead of scraping along in a hand-to-mouth way, or even falling over the edge into failure. But that is looking at the problem from the producer's angle only: the consumer is another matter. And there for the moment the trouble is serious. You have very large sections of our 40 millions of people not getting all they would like to eat, and quite considerable sections definitely getting too little for full health and growth and energy; and yet there is restriction of output and even destruction of food, as when herrings are thrown away or milk poured down the drains to keep the price up.

That, however, is not the fault of science, but of our economic system, and how that is to be remedied is a question for economists and administrators. Meanwhile it does lie like a barrier across our hopes for a well-nourished, healthy nation. But the hopes are there, and if the barrier of the economic system seems strong,

the basis of the hope is strong too! And that basis is the certitude that science, if its existing knowledge were properly applied, could at least double the amount of food we produce in these little islands, and could put up world-production to a level at which there would be enough and to spare for the 2000 million human beings in existence.

CHAPTER IV

SCIENCE AND BUILDING

IN this chapter I want to say something about science in its relation to the art and business of building and construction, and I want to begin by asking you to think of the rather curious contrast between the motor industry and the building industry. Here, as elsewhere, the Great War makes a convenient landmark. In the years since the end of the War, the quality and convenience of motor-cars have been improved out of all recognition, their price has in general gone down, and the supply has been adequate to meet the demand. With houses, on the other hand, the supply has been far from adequate, their price has in general gone up, and their quality and convenience have remained stationary, or at best been slightly improved.

This contrast is undoubtedly linked up with the contrast in the method of production in the two cases. With motor-cars, the outstanding features are rapid mass-production in the factory on the one hand, and on the other intensive research and invention, with speedy utilization of their results. With houses, on the contrary, the structure is slowly built up on the site, and it is fair to say that traditional methods both of production and construction have remained in the saddle.

There is, however, a further fact. There have not

been wanting men to notice this contrast, and to try to remedy it by applying the methods of mass-production and modern technology to housing. At one time, for instance, it was steel houses that were going to revolutionize the industry, at another cottages made of concrete cast in moulds. But so far none of these attempts has been wholly successful. Some of the reasons for this have at first sight seemed to be unconnected with the merits of the schemes—for instance, the resistance of the building trades unions to the schemes for providing steel houses, on the ground that they would not only throw the traditional building crafts into chaos, but would also largely substitute unskilled for skilled labour. But in the final reckoning, the reason for the failure of these projects is that they have deserved to fail—because they have not provided an article suited for its purpose.

One frequent trouble with the steel houses, for instance, was corrosion of the steel skin. Men used to steel construction in other fields, such as shipbuilding, reply that they have got over the corrosion trouble there. To do so, however, means constant painting at frequent intervals; and to have an army of painters going over all the houses in a neighbourhood as often as they go over a ship's hull would mean a radical change in outlook on the part of builders, local authorities, and, most of all, of the occupiers of the houses, to whom it would be an infernal nuisance, let alone preventing them growing creepers up their walls. Another trouble was condensation: the houses were cheap to put up, but when they were lived in, it was found that moisture often condensed on their ceilings and walls in a most unpleasant way.

In other words, the problem had been looked at from the standpoint of cheap construction only; the comfort and convenience of the user had not been properly taken into account.

So far, that has been the trouble with all attempts to apply mass-production to housing; the promoters have forgotten to think of *all* the needs which a good house stands for. Of course, shelter is the most obvious need catered for by a house. But shelter does not mean merely having a roof over your head: it means also being protected from cold and wet; and, further, it means privacy—protection from the distractions of the rest of the world, and especially from noise.

The old type of house, produced by traditional methods without any thought of science, did on the whole stand up to all these demands. When properly built, its thick walls of brick or stone allowed only a slow passage of heat, so that rooms could be kept warm in winter and cool in summer; they did not allow the rain to come through, nor permit much condensation of moisture inside; and on the whole they cut off noise very efficiently. On the other hand, such houses took a long time to put up, and used a very large amount of material.

The one really radical change in building methods which is based upon science is the modern framed building of steel or reinforced concrete. This makes possible a considerable economy in construction by demanding less material in the walls: the frame takes all the weight, and the walls, relieved of the need for providing support, can be made much thinner. But when you try to effect this economy, you are at once up against difficulties. If you economize on outer walls,

you are likely to lose heat too quickly; if you economize on inner walls, you are likely to get noise passing too easily from room to room (Where the building is a block of flats, this is especially serious: members of a family tolerate each other's noise much more readily than they do the noise made by the family next door!) In addition, the new construction brings new difficulties of its own: the pipes, steel beams, and so on which run long distances through the building, provide excellent channels along which sound can travel The result, in some otherwise admirable modern buildings, is a nightmare of noise.

Last week I visited the Building Research Station out at Watford, which is one of the research institutions under the Department of Scientific and Industrial Research; I saw the work that was going on there, and had a long talk with the Director, Dr. Stradling. His job, as he explained to me, is first and foremost to see the problem as a whole. There is a very real need for economy in construction if we are to have decent houses at a reasonable price. There is a need for rapidity in construction, not only for economy's sake, but also because the country needs a great many new buildings, and needs them quickly. But the materials and the design must be such that damp or sound does not pass through too readily, that the fabric is resistant to decay and corrosion, that moisture does not condense inside, that there is decent ventilation, and that the general layout is convenient.

The excellent building methods of earlier centuries were the result of good craftsmanship based on tradition, and the craftsmanship and the tradition were essentially local, and represented experience in dealing with locally-

favoured building material. The effect of modern conditions has been a mix-up. Ease of transport and communications not only brings slate to areas where tiles have been traditional, bricks to regions accustomed to build in stone, and so on, but also brings the building craftsman from one area to another where his particular skill no longer applies. Traditions were once adapted to materials. now they are all jumbled higgledy-piggledy.

Stradling illustrated his point from plastering. There are many sources of lime in Britain. The different limes come from different natural deposits and possess different physical and chemical properties—in the rate of setting, for instance—and hence each requires a different technique in the handling.

In the old days there were as many traditions of the plasterer's craft as there are different varieties of lime in the country. To-day the plasterer, confronted with some new brand of lime he has not been brought up on, may make little mistakes which yet may have disastrous results—such as the cracking off of all the plaster. The modern pressure on speed in construction also introduces a variation on all traditional methods, and often makes little errors more serious in their results

Stradling was quite definite as to the right line to pursue For one thing, he believes that good craftsmanship is still, and will for some time continue to be, the basis of good building. The time *may* come, he agreed, when houses can be mass-produced—the different ingredients, such as steel frame, walls, glass, plumbing, and so on, made on a large scale, in different factories, and then assembled, rather as a car is assembled, by a specialist firm; and people will discuss

the date and brand of their houses as they now do of their cars But before that is possible, a great deal of research will have had to be undertaken, let alone changes in business organization and social outlook. Meanwhile we must pin our faith to craftsmanship, and craftsmanship means a good rule-of-thumb; after that has been mastered, it is possible to think of beauty.

But—and this is where research comes in—there is no reason for a rule-of-thumb to be unscientific. The first need to-day in building research is to find out the scientific bases for traditional methods The second is to get really accurate standard specifications for materials. The two points, of course, link with each other, for a good tradition can only grow up with a uniform material to work on.

To go back to our example of plastering, a great deal of research has recently been going on to find the best mixtures which will combine ease of working, strength, rigid setting, and other desirable properties—with a good deal of success. But this does not dispense with the need for rule-of-thumb In fact, you want the rule-of-thumb procedure very carefully laid down, so that craftsmen accustomed to other traditions shall not make little mistakes which may upset the whole process.

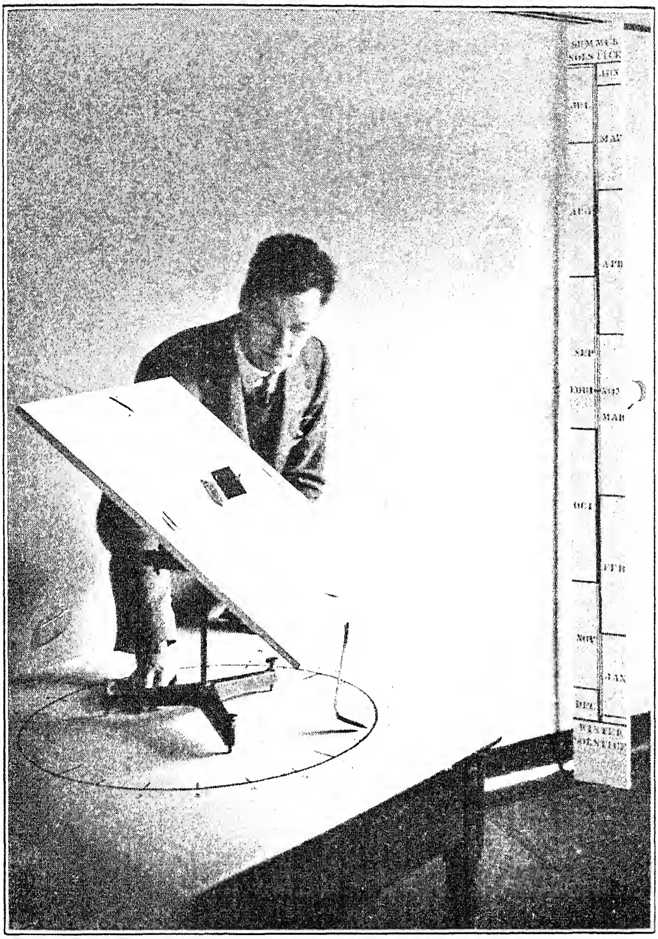
If you have standard materials, you can work out a scientific method of treatment for them; and if you have this scientific basis, you arrive at a rule-of-thumb which can be reasonable, communicable, and flexible, instead of rigid, traditional, and obstinate.

So that perhaps the main aims of the Station are to get materials standardized, so that architects, builders, and craftsmen shall know what they are dealing with, and to work out the scientific basis for the treatment

of the materials, on which to build up a new and intelligent tradition of craftsmanship. This must be done for quite new materials and processes, like concrete and steel construction, just as much as for old ones, like lime or brickwork.

But a great deal of research is also going on here in special fields affecting the comfort of the house-user, such as those which concern warmth and noise. One bit of work of this type concerns what has been called sun-planning—siting and designing a house so as to get the maximum amount of sunshine. This can be dealt with if a specialist is called in who knows all about calculating the exact direction of sunshine at different hours of the day and different seasons of the year in different latitudes; but a much simpler method has been devised at Watford by using a scale model of the building. The model is put on a board which can be tilted to represent the surface of the earth in the latitude of the site. The sun is represented by a lamp. This is made to slide up and down a board to represent the position of the sun at any time of the year, while the board is made to rotate to represent the effect of the earth spinning on its axis every twenty-four hours. By means of this, the amount of sunshine which will fall on the outside of a house and get in through the window at any hour and any day in the year can be at once made visibly apparent.

Then, in the grounds of the Station is an "experimental house" for work on heating. But even though it was specially designed for the work, the variations in our English weather made it difficult to carry out the necessary researches, and now they are going to put up an experimental house inside another house, or rather



Science in the service of comfort and health. The heliodon at the Building Research Station, Watford: an instrument for determining the exact amount of sunshine which a house will receive at any hour or any day in the year. The sun is represented by the electric-light bulb on the right. The time of day is marked on the circle on the table. (*See* p. 56.)

By permission of the Controller of H.M. Stationery Office.

The "bricks' cemetery" at the Building Research Station at Watford, where different kinds of bricks are tested for their durability underground. The photograph was taken before the bricks were buried in the earth. (*See* p. 60).

From *Building Research Report for* 1932.

By permission of the Controller of H.M. Stationery Office.

inside another set of walls and roof. Then they will be able to make artificially whatever weather they like outside the experimental house by controlling the temperature and moisture and other atmospheric conditions in the space between it and the outer shell. Valuable information is already being obtained as to the heat-retaining qualities of various types of panellings and so on.

In addition, attempts are being made to reduce problems of human comfort to scientific terms. Our human bodies are sensitive not merely to the temperature, but also to humidity, air currents, and other factors. A rather elaborate apparatus has been devised to give a definite measure of as many of these factors as possible; and with this, measurements are being made under various conditions of ventilation and heating system. This particular work is only in its infancy, and much co-operation will be needed with bodies like the Medical Research Council; but it is bound to throw a great deal of light on all the new problems arising from the introduction of new types of heating like gas-fires, and those like central heating and electric radiation which demand no draught, and therefore dispense with chimneys and flues—and in general is certain to make life more comfortable.

The sound problems are just as interesting. The testing on the practical side is done at Watford, but the fundamental research is mostly being carried out at the National Physical Laboratory at Teddington, and also in the laboratories of Metro-Vickers at Manchester and in other laboratories which I did not have an opportunity of seeing.

In this field, again, questions of human comfort are

much to the fore. It is an interesting fact that if we take a series of sounds increasing in intensity, and if to our ears and brains the steps in increasing loudness all seem to be equal, the actual physical energy needed to make the sound has to be multiplied by the same amount each time. For sounds of intensity one, two, three, say, the amount of physical energy will be one, ten, a hundred. However, this rule is only approximate: it is slightly different for different kinds of sounds, and does not hold for very faint and very loud sounds. Research linking the physical side of sound production with the physiological side of our hearing of it is in progress, and will be of the greatest importance if ever we seriously set about tackling the business of reducing the unnecessary noise generated by our so-called civilization.

Immediate results are also being obtained in preventing reverberation and echoes. One room at Teddington has been deliberately built to give an abominable reverberation. The intensity of the reverberation can be measured; then a definite area of some material designed to prevent reverberation is put on the walls, and the noise again measured. In a very few years there should be no excuse for reverberating noises in a building.

Echoes are studied by means of tiny models representing sections along and across a theatre, or concert-hall, or whatever the building may be. By an electrical device, a wave of disturbance in the air is set up at a spot corresponding to the stage in the model, and can be actually photographed as it travels to and fro within the model; and this shows just how the design can be corrected for echoes and dead spaces.

The worst problems, however, are those of sound transmission through partitions: here large-scale work is beginning. It is very laborious, but in a few years there ought to be really valuable results.

The National Physical Laboratory reminds me that the construction of buildings is not the only kind of construction. There are bridges and all sorts of other engineering structures to be thought of For the erection of these, of course, all kinds of scientific research, from pure mathematics down to elaborate testing of stresses and strains, is absolutely necessary.

One series of researches at the National Physical Laboratory is dealing with a new process in steel-working—the making of joints by electric welding instead of riveting. In electric welding an electric arc is used, and actually melts the two bits of steel together But as yet little is known as to the limits of strength of joints made in this way and the best methods of using the procedure. Elaborate tests are now being made, and we shall soon know the safety factor, and consequently where the new invention can rightly be used. Similar tests on bolting and rivetting and on steel-frame joints in general are being carried out on full-scale models in the Civil Engineering Department of Birmingham University. These, with other tests at Watford, which are made on a large-scale steel frame erected as for a building, are part of a big scheme of research which should lead to an appreciable reduction in the cost of steel construction.

Then new alloys are being tested out, not only for steel construction (the new steels are really more essential for other branches of industry), but also for plumbing. Some of the new lead alloys on which the

Non-Ferrous Metals Research Association is working are likely to do away with many troubles that now beset the builder or the householder.

Coming back to the Station at Watford, I must try to bring before you some of the particular bits of research I saw going on there. One very simple experiment concerns the testing of brick. Brick samples from all over the country are stuck upright in the soil, half buried, and left there for a year. The effect on the spectator is that of a large cemetery on a small scale; and the effect on some of the bricks is very serious! If they happen to be under-burnt, or to have certain kinds of salts in their composition, they crack and split. There are plenty of other tests on bricks too, the general aim being to ensure a higher quality and a more uniform standard.

Then there are researches on the weathering of stone. Gradually a series of laboratory tests is being worked out which will enable an accurate prophecy to be made of a stone's resistance to ordinary weathering and to corrosion by noxious gases (it will be news to most people that even in the country noxious gases do the greater harm: they get blown there from the towns!). These tests are not only more reliable than the estimates given even by the most experienced stone-masons and architects: they are sometimes right when experience is wrong.

Then there was some fascinating work in progress on the subject of pile-driving. At the moment, concrete piles are much in vogue; but when they meet a hard layer, sometimes they splinter and mushroom out at the foot, or break slantwise so that the top half is forced down alongside the bottom half. To avoid these

accidents, which at best cause the loss of the piles, and at worst may endanger the safety of the construction they are to support, it is necessary to know just what forces a pile will stand, and to just what forces it is actually subjected. Now, quartz, as was found out by pure physicists in academic laboratories, has the curious property of altering its electrical resistance under pressure. So quartz crystals with wires attached are cast actually in the interior of a concrete pile, and then the pile is driven with different degrees of force through material of different hardness An electric current is sent through the quartz all the time, and its variations are automatically recorded by the aid of a special cathode-ray tube. Help in the design of this and the rest of the electrical part of the apparatus was got by the Building Research Station from the Radio Research Station, another of the institutions under the Department of Scientific and Industrial Research, a fact which excellently illustrates the advantages of proper co-operative organization in research.

Bang comes the pile-driver on the head of the pile; the quartz is squeezed; the flow of electric current is altered; the alteration, translated into terms of light, is recorded on a photographic film; and from the amount of the alteration, the exact pressure inside the pile can be accurately calculated. In a year or so there will be no excuse for broken piles.

Then there is the special laboratory, recently finished for research on concrete—much the best-equipped in the world. Its atmosphere is maintained under constant conditions of temperature and humidity—a necessity for the scientific study of a material like concrete, which alters its properties with the temperature,

and especially with the amount of moisture it contains. So far the mixing of concrete, even on the largest scale, has been rather a haphazard business; in this laboratory trained chemists are working out the exact changes in its composition and properties which are brought about by altering the proportions of its ingredients and the temperature at which it is melted in the kilns. For this, miniature furnaces are needed in which the temperature can be controlled and recorded. By means of an electrical regulating device (again made possible by earlier research in pure physics), these furnaces can be held at temperatures up to nearly 3,000° F. with a variation of less than a degree! If they take advantage of the results of this work, manufacturers will soon be able to produce concrete to any particular specification as required.

A queer little piece of research began with the accidental noting of the fact that certain types of slate exposed to high temperatures swell up rather like a Pharaoh's serpent. These are mostly of poor quality as slate, but the new porous material produced from them by heating can be profitably used for lightening concrete and other heavy materials.

It is quite clear, I hope you will agree, that research is doing a great deal for building. It is laying the basis for a craftsmanship based on scientific knowledge instead of half-conscious tradition. It is making it possible to prepare standards for all the multitude of materials and objects used in building. This might enable us to reduce the waste of mere variety, and to raise quality; we might also have many more standards not only laid down on paper, but actually enforced through by-laws and regulations. It is

helping with the introduction and testing of new building materials, like steel, concrete, synthetic stone, and the like. It is paying attention to fundamentals of housing comfort such as heating, ventilation, and sound-proofing.

But with all this there remain the obstinate facts of the housing situation. Many of us cheerfully abuse the Soviet system for the terrible overcrowding still to be found in Moscow and other big Russian cities; but we are prone to forget the overcrowding to be found in our own country.

I saw it stated the other day that one-fifth of our population is living in slums—or in poverty verging on slums: that is, eight million human beings. I need not remind you of the vast areas scheduled for slum clearance under the present Ministry of Health campaign. Sir Hilton Young said that he could foresee, from the returns already come in, that in five years, two hundred thousand houses would be cleared and considerably over one million people re-housed. And many authorities do not consider this nearly enough.

The trouble about slums and poor housing in general is primarily economic. Excellent houses can be built all right; but to let them to working-class families at an economic rent is another story. When one begins to look into the reason for this, a whole tangle of causes appears—the demand of the ground landlord and the owner of houses for returns on their property; taxation and rates; unplanned cities with transport difficulties for their army of working people; the rate of wages, and so on. In the main, I think it is fair to say that there is an acute conflict between two views: the views of those who regard housing as a social service on a par

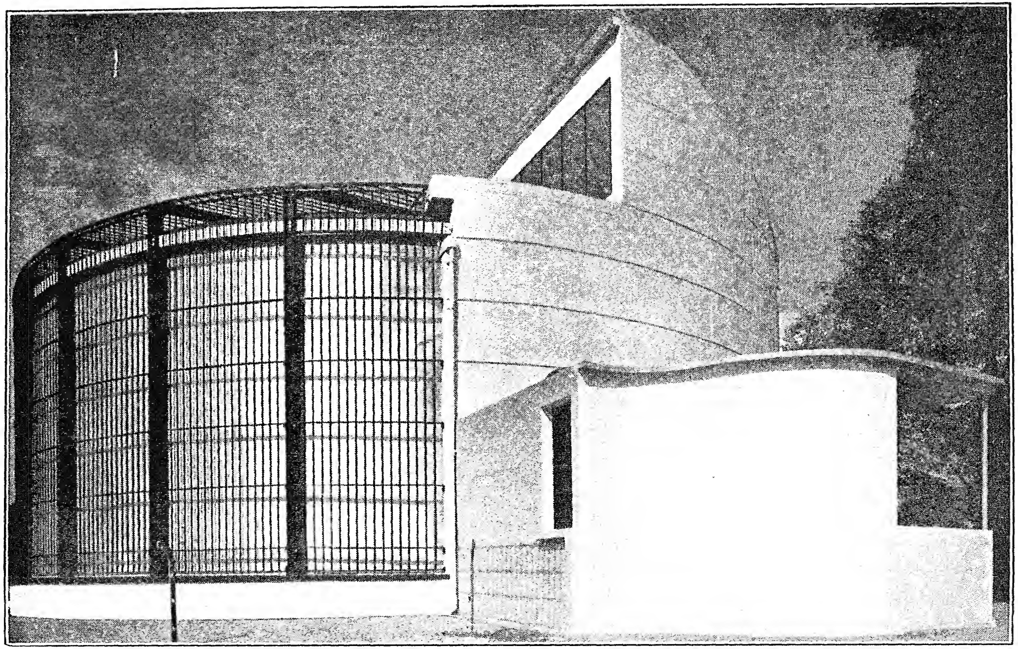
with roads and water-supply and sanitation, and those who regard it as a commodity to be supplied at a profit, the profit coming first, and all other considerations being secondary.

To mitigate the abuses arising out of the crude application of this second view, you may insist on a certain amount of state or municipal control of conditions. This is the view which the Minister of Health has just voiced, when he said that to make a profit out of insanitary slum-dwellings was on a par with selling diseased meat. The full-blown advocate of the social service idea, however, believes that proper housing is so vitally important not only for people's physical health, but also for their happiness and their general background of life and thought, that if private enterprise cannot provide it on terms satisfactory to itself, the state or the city must step in (as the city authorities have done in Vienna) and provide it out of general funds, just as they do roads or sewers or street lighting or education. Why not, for instance, treat housing as a public utility on a national scale, and establish a National Housing Corporation on the same sort of pattern as the British Broadcasting Corporation? I am afraid a lot of you will be thinking that I am straying beyond my province into that of the economist and the politician. But really I am not. The more I see of the way science is or is not being applied to practical social needs, the clearer it becomes how much the question is mixed up with economics and politics.

However great may be the possible applications of scientific research, some form of pressure is needed to translate possibility into actuality. Sometimes private profit provides the driving force, as with most industrial

L.E.A.

A contrast in housing. Compare these human habitations—in the slums—



with this home for apes—at the London Zoo. (*See* p. 66.)
By courtesy of Tecton, the architects.

applications of research; sometimes military needs, as with naval construction, poison gas, or new types of fighting aeroplanes; sometimes it is a more or less pure social aim, as with medical research. With building, private profit combined with a certain amount of government organization of research is capable of showing how to build cheaper, better, and more comfortable houses; but can it get them universally built? The upholders of private enterprise say "Yes." But there is a strong body of opinion which says "No," and believes that other kinds of driving force are necessary before the results of research can be fully translated into practical applications—and with this latter opinion I am inclined to agree.

During the discussion between Professor Levy and myself, in the last chapter, a point cropped up about the absence of state-aided Research Councils in the fields of economics and social science. Is this where a partial remedy lies for building? Of the existing research on building, an important section is concerned with the comfort of the users—of you and me and all the rest of the population who have to live and work in buildings. The rest of it is concerned with cutting down costs of production—production of the actual tangible building with its fittings. But the cost of a building to the man who lives or works in it depends on a great many other things as well—notably on the cost of the land on which it is built, the costs of developing the site with roads and light and water-mains, the rates and taxes, and so on. We want research on such problems too. At the moment, we have no knowledge of even the basic facts: for instance, there is no full national survey of land ownership in existence.

Then, the convenience of a building depends a great deal on its surroundings, which means proper planning. Land ownership, town planning, the system of rating—all these are factors in the cost and convenience of building; it may be suggested that fifty years hence state-aided building research will have concerned itself with these as well as with problems of building construction and design; and that by then our social needs in the matter will be properly catered for, in the erstwhile slums as well as in high-class residential districts, and there will no longer be the lamentable contrast between the accommodation provided for the gorillas at the London Zoo and the human population of our towns.

CHAPTER V

SCIENCE AND CLOTHING

THE clothing industry, like that of building, is for the most part traditional. In the building industry there is one section—that of frame-construction with steel or reinforced concrete—where there is no link with traditional methods The same is true of clothing: the only wholly untraditional section is the artificial-silk industry. In some cases, old methods have persisted into the present century. While visiting the Professor of Leather Chemistry at Leeds University, I saw hanging on his wall a photograph of a tan-pit at Falaise in Normandy taken some thirty years ago. The pit is known to have been a going concern in the eleventh century (in fact, the father of William the Conqueror fell in love with the daughter of the tanner who worked it, and William the Conqueror was the result, so that tan-pit had a strong influence on English history). It had been operated unchanged till the photograph was taken; and for all I know may still be going strong

But while the making of fabrics out of vegetable fibres like cotton or flax, and animal fibres like wool, has come down to us from antiquity, the modern methods of achieving these ends have been radically transformed. A Roman building foreman would have understood most of the work of a building foreman

to-day. But a Roman woman, expert with her spinning-wheel, would not be able to recognize spinning when she saw it going on in a Lancashire mill, any more than an African weaver would understand what a modern power-loom was doing. Thanks to new sources of power (in the shape of water-power, steam, and electricity) and to mechanical invention (in the shape of astonishing machines), the tradition of textile manufacture has been changed much more than has the tradition of building. None the less, the industry still operates almost entirely with traditional materials, and for the most part by means of methods which, when not traditional in the narrower sense, have been improved by invention rather than by science. There have been thousands of years of experience behind the traditional practices, and enormous financial premiums on successful inventions, so that it might at first sight be thought that there would be little room for new improvements based on the method of science. It will be my business in this chapter to discuss whether this is so or not.

In the past there have been, of course, very real advances in textile processes which have been due to science. I will take only one example—bleaching. How many people realize that up till the late eighteenth century it took a whole summer to bleach a piece of cloth? The cloth, after being treated with a caustic substance, was spread out on the grass, so that big bleaching fields were needed. Then, however, the chemists discovered chlorine gas and its bleaching properties, and now, by the aid of compounds containing chlorine, bleaching can be done in a short time and in the small space provided by a factory. This is lucky,

for otherwise about half the countryside of England would be covered with pieces of cotton and linen!—in other words, modern output would be altogether impossible

In the course of my tour I saw a number of places in which science is being used to study the processes concerned with our clothing—some of these were Research Associations under the Department of Scientific and Industrial Research—one for cotton, one for wool, one for leather, and one for that rather different aspect of the problem, laundering. Others were University departments—for leather chemistry and for textile research. Others were private firms, such as one engaged in improving the machinery for making boots and shoes, and another doing the same for knitting machinery. Then other laboratories which I have visited earlier were incidentally concerned with other aspects of this problem—for instance, the Animal Breeding Research Department at Edinburgh with rabbit-breeding for fur and sheep-breeding for wool, and the Rowett Institute at Aberdeen with the food of sheep and the quality of their wool; and there are plenty of other laboratories which I had not the time to visit—concerned with linen, with real silk and artificial silk, with boot- and shoe-making, with cotton-breeding and cotton-growing, and with that very important branch of the industry, dyeing.

The first thing that struck me with all this array of research is the amount of it that goes to improve traditional methods and standards by giving them a scientific foundation. I said something about this in the previous chapter, and pointed out how important it was in relation to building. It is, I am sure, equally

important for all industries, and especially for those with a strong traditional basis.

For one thing, it prevents tradition from being dumb and unintelligent, and provides a method for communicating its results; for another it improves the accuracy of traditional methods, and so helps both to standardize them and improve them. The skilled craftsman accustomed to carrying out some process, if asked how he is sure the conditions are right, will often tell you he just *knows*, by experience. He could not explain his knowledge to another person, nor could he write down just what was necessary if the conditions were to be reproduced: he simply knows when they are right. Generally he does know in an almost uncanny way, considering that he is unprovided with accurate instruments and methods to give him any precise measurement—and often in this way he knows things which we cannot yet measure and describe accurately.

But whenever it *is* possible to introduce scientific methods of measurement, it is found, as a matter of hard fact, that the standard of accuracy goes up. It goes up even for the individual craftsman; but it goes up still more for the industry as a whole, because then you have measurable standards which can be written down and be used as a common basis for correcting the individual prejudices and personal foibles of different craftsmen.

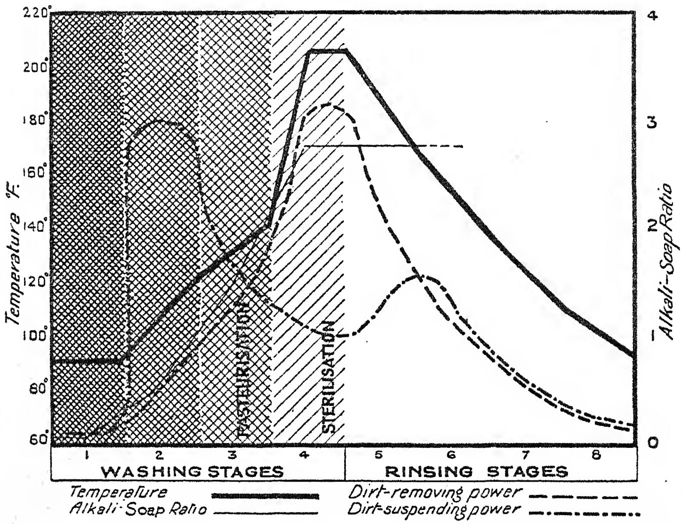
I should like to give a few examples of this from different sides of the field of my subject. Take laundering as a concrete example that comes right home to everybody. In a modern laundry, your collars, after washing, are passed round a metal roller,

heated by gas. This ought to be at a particular temperature to give the best results, and the temperature ought not to vary more than a small amount if you are to avoid various undesirable effects, such as collars getting scorched, or going limp afterwards, and so on. The traditional, and still widely practised method of telling the temperature, is to spit on the finger, transfer the spit to the hot roller, and tell from the particular sort of crackling it makes if conditions are right. With an experienced man this gives really remarkable results, but at the very best, as scientific research found, you have to expect a variation of not less than fifty degrees or so either way. Science then went further, and designed an automatic temperature-regulator, which can be set to keep the machine at any desired temperature, with only about five degrees variation There is no excuse for collars spoilt by wrong temperatures now.

Just the same sort of thing has been done for the temperature of the finishing machinery used for wool. Finish used to be a very tricky quality. But now it is possible to reproduce a finish over and over again by means of having accurate control of the conditions.

Then take leather research Here an enormous amount of work has been done, not only to standardize the tannin content of various substances used for tanning, but also to standardize the physical and chemical conditions under which tanning should take place to give the best results; by means of chemical indicators and the like, the tanning expert can now make accurate tests all the time to see if his vats are providing the best conditions. In the same way, it has been found with wool that the conditions under which the wool is

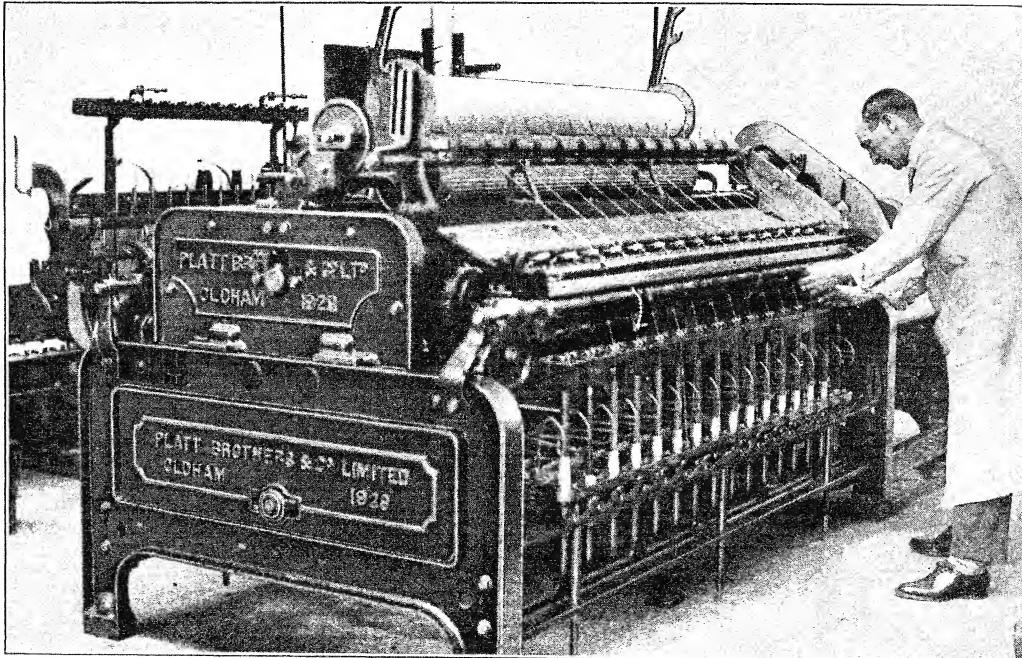
to be "scoured," or freed from its natural grease and from dirt, have got to proceed within certain definite limits of temperature and of alkalinity if the wool is not to be damaged; and science can not only measure these limits, but can also produce fool-proof gadgets to test for them in the works.



[*By courtesy of the British Launderers' Research Association.*

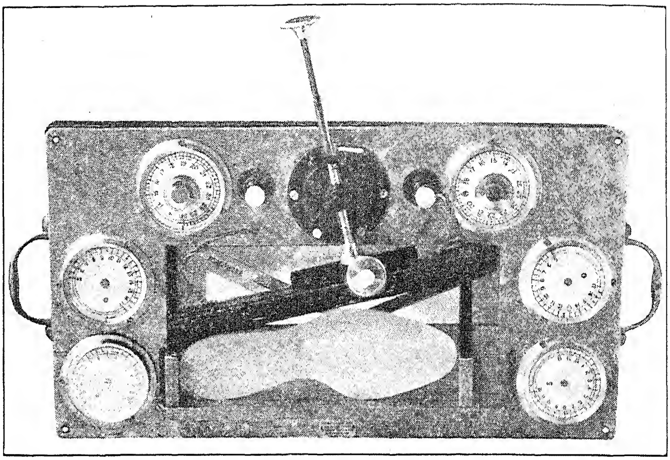
Science in the laundry industry. A diagram showing quantitatively the best conditions for carrying out the washing process. The temperature and the ratio of alkali to soap must be changed as indicated in order to get a proper balance between dirt-suspending and dirt-removing power. The shading indicates the progressive removal of dirt from the fabrics.

With cotton, too, we find the same steady improvement in technical process as a result of the accuracy which only scientific research can provide in communicable form. Different cottons are now laboriously standardized in relation to the length of their fibres—



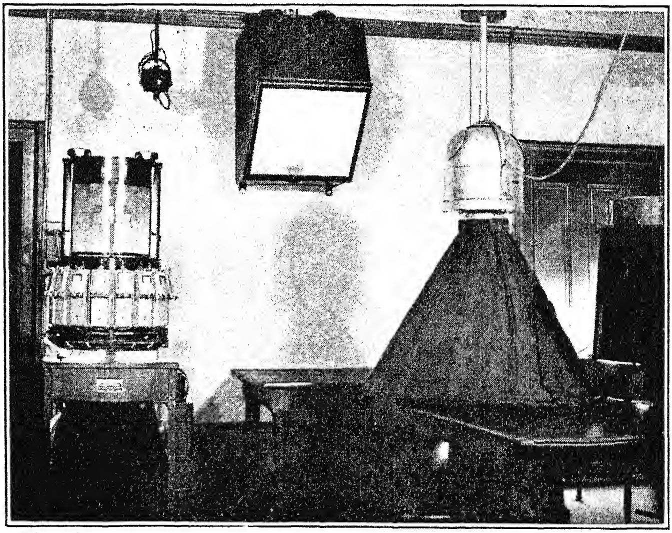
Planned design in the woollen industry. A new type of wool-spinning machine, with a ring spinning frame, designed by the staff of the Wool Industries Research Association at Leeds. (*See* p. 73.)

By courtesy of the British Research Association for the Woollen and Worsted Industries.



Scientific accuracy in the shoe industry. An instrument for measuring feet, designed to supply manufacturers with the information they need as regards the classification of types of feet and the specification for properly-fitting shoes for each type.

By courtesy of the British Boot, Shoe, and Allied Trades Research Association.



Applied physics and the woollen industry, Left, a sunlight lamp employed to test the fading of dyed patterns. Centre, a matching lamp, for comparing colours. Right, an ultra-violet lamp, for detecting certain qualities in fabrics.

By courtesy of the British Research Association for the Woollen and Worsted Industries.

both its average, and the amount of its variation from the average; on such data, which need a special type of mathematical treatment before you can employ them, pronouncements can be made as to the precise uses the different cottons should be put to, and the details of their spinning. Or again, cotton fibres could never stand up to the strain to which they are subjected in the machines if they were not first strengthened by being dipped in size; and there again science is helping a great deal to standardize and improve the treatment.

I have spent a good deal of time on this point, because it is very important. This sort of research is rarely spectacular; but it is absolutely necessary. It is the only way in which an industry, especially an industry of long standing which has grown up in the pre-scientific era, can improve the efficiency of its established processes to any large extent and with any reasonable speed, and the increase of efficiency may be considerable. At the Wool Research Association I saw a new carding machine which was the result simply of a painstaking scientific analysis of all the factors that enter into the operation of carding wool, followed by the designing and building of a machine meant to cope with all the problems in the most efficient way. The result was a machine which was not only more efficient and quicker in its working, but also took up only one half of the space of the old machines; an even greater saving of space and increase of efficiency is being achieved with a specially designed new spinning machine. Think what this means to a factory owner!

But I must not continue longer on this aspect of research, for there are plenty of others of interest. Science, for instance, can be applied in the interest of

workers in the industry or of the consumer of its products. Everyone knows how aggravating it is when a nice new bathing-dress shrinks so that you can hardly get into it, or splits so that you begin to get out of it in the wrong place. This trouble has been much accentuated by the spread of sun-bathing, and the research workers at the Wool Research Association have been looking into it scientifically. Their findings were quite definite. It is not merely or mainly the sea-water and the drying that are to blame. One chief cause is the ultra-violet rays in sunlight, which damage the intimate structure of wool much as they do the intimate structure of the living cells of our bodies. The other is the presence in sea-water of certain kinds of bacteria—quite harmless from the point of view of causing disease—which, when nicely warmed up by the heat of the sun outside and of a human body inside, get very active, and begin to rot the wool The workers at the Research Association have now got an antiseptic which will discourage the germs; they have a treatment to make wool much more resistant to ultra-violet; and they also have a new process (it too based on scientific research) for preventing shrinkage. Bathers should be happier next year.

In another room at the same institution a vigorous anti-clothes-moth campaign is being carried on, with a good deal of success. Some of the work is being done in connection with the Forest Products Research Station, and boxes of cedar and other Empire aromatic woods are being tested for their qualities in keeping moths away.

Then there is the comfort of clothes. This depends largely on the ease with which air can get through

the fabric—as everyone knows, the thinnest sheet of an impermeable stuff is much more uncomfortable than a thick layer of some cellular material. So instruments have been devised to test this property of fabrics in a quantitative way. Air is blown through a vertical tube under standard pressures, first without and then with a piece of the fabric interposed in the path of the air-current. In the tube is an ingenious device—a little metal object with screw vanes, which is supported by the air-pressure as a celluloid ball can be suspended in the jet of a fountain The resistance offered by the fabric is measured by the difference in the height at which this object is held up in the tube by the air-current

By such means we can get a fixed rating for the permeability of a fabric to air; and fixed ratings are the first step towards improved standards. Similar work is being done by the Boot and Shoe Trade Research Association—only here the problem is more complicated, as you want to raise the standard of leather both for [illegible] the passing through of water, and for [illegible] that of air

If I had space I could describe a rather amusing piece of work carried out by the Wool Research Association which started with a complaint from a woman who had been cooking, and whose jumper changed colour only on the front—the side towards the heat—and led to improved methods of preventing white flannels from turning yellow. But I must pass on to an interesting point about the workers. Spinners' cancer is an all-too-prevalent disease among spinning operatives. It is probably due to a certain kind of mineral oil used on the bar of the machine, with

which they repeatedly come in contact in their work Cancer-research workers have found that mixing lanoline (itself derived from sheep fat) with mineral oils reduces the chance of these oils giving cancer to mice, and, of course, the next step will be to try the method out in the mills The pleasant irony of the situation is that lanoline is itself a product of the fat got out of wool in cleaning: the fat has to be taken out of the wool, and the disposal of it is quite a problem It is interesting to find that alcohol derived from this same fat is now being used to clean off the mineral oils used in combing wool—and the action seems to be more or less the same here as with that of lanoline in the case of cancer.

Next we come to cases where science has made possible rather big jumps, instead of helping the gradual improvement of processes. I spoke earlier of the big jump in bleaching methods made possible by the discovery of chlorine gas But chlorine bleaching, if excessive, will damage the fabric; so it is important to have a quantitative test for its effects Now, in the course of research on cotton, it was found that the cellulose material of which the cotton fibre is composed can be dissolved in a chemical substance called cupr-ammonium sulphate. What is more, it dissolves in a different way according as to whether it is unaltered cellulose or cellulose damaged by such processes as over-bleaching, so that its fluidity is different in the two cases. This had provided quite a big improvement for the launderer. By putting into cuprammonium sulphate samples of cotton fabric bleached in various ways, and then measuring the ease of flow of the resulting solutions, you can get a direct measure

of the damage, if any, done by the bleaching; and so, of course, improve and standardize the processes used for bleaching in laundries. The basic fact here, let me repeat, was discovered in the course of general research into the physical and chemical constitution of cotton fabrics.

Now let me skip to something quite different. Most people whose memories date back to pre-war days probably think of a tannery as a nasty smelly place which they would much rather not have in their neighbourhood This was largely due to the fact that in one of the fundamental processes of preparing leather out of hides—bating or puering, as it is called—the dung of animals was a necessary and considerable ingredient. Dog's dung was the usual material, but for certain purposes other equally unpleasant substances like fowl and pigeon dung were favourites. Then, about twenty years ago, an English chemist, Wood of Nottingham, got busy. He discovered that the substance in the dung which was responsible for the desired effect was trypsin, the well-known ferment which we and other animals produce to digest the protein part of our food; and now a preparation of trypsin made from the sweetbreads of animals is almost universally used in tanneries in place of dung, with not only a great increase in cleanliness and decrease in smelliness, but also a definite improvement in results, because you can be more accurate when using a pure substance.

Or take another very different example of a big change as the result of scientific research—the crease-resisting cotton ("creaseless cotton" as it is often popularly called), put on the market recently by

one of the big cotton firms. The history of this fabric is interesting. In order to achieve its production, the head of the firm engaged the services of two scientists, a physicist and a chemist He took in one hand a piece of wool fabric, in the other a piece of cotton fabric of the same size and weight, and crumpled both pieces into a ball Then he opened his hands again; the wool, with its natural elasticity, uncreased itself, but the cotton stayed crumpled. "I want you," he said, "to make cotton fabric which will behave like the wool; take ten years if you like" They tried everything, from india-rubber to gum and back again; and tried them scientifically, not just hit-or-miss. Eventually they got a synthetic substance whose molecules would slip nicely into the cotton fibres and give them elasticity. But instead of ten years it was fourteen before the new fabric was on the market. This well shows not only what slow slogging research, backed by scientific methods, can do, but also what a long and difficult job it can be.

And of course there is rayon itself—artificial silk. I have not space to say much about this active new industry, except that it is very much the child of science. When people first had the idea of making artificial fibres by dissolving cellulose and squirting it through holes under pressure, the process itself depended on facts and methods discovered in laboratories of pure chemistry. Then, the product in those early years was far from satisfactory—it curled and crinkled, it dyed patchily, it shrank, it went to pieces under very slight provocation. Constant scientific research on all the processes involved has turned it into the really

lovely material available to-day—a new gift of science to the world.

Before going further, I would like to give one more example, to show how research is being focussed on our problem from very different angles. One of the research workers in the Animal Breeding Research Department at Edinburgh is engaged in applying Mendel's principles of heredity to practical rabbit-breeding. He showed me a whole series of the latest types of rabbit pelts for use in the fur trade. There was one which, until you actually handled it, was an excellent imitation of silver fox—the same dark hair with white ticking. He had made this himself, by introducing the hereditary factor for dark colour from one breed, and the factor which causes the white ticking from another breed of quite a different colour. Then there were really wonderful imitations of sable. These he had not created himself; but he had cleared up a puzzle of why they never bred true, and shown breeders how to produce 100 per cent. sables by breeding two quite different-looking pure breeds together. This was again an application of simple Mendelian principles. Imitations of silver fox and grey squirrel, of marten, of plush, of caracul—all these he showed me too. Furs are only a small branch of clothing; but they are important for their social implications: cheap furs, like artificial silk, make it possible for women with small incomes to feel smart and fashionable.

So I could go on, only that I have not space. I must, however, just mention one line of research that is giving the most fundamental and revolutionary results—and that is the application of X-ray photography to textile fibres. X-ray photography is a

method for revealing to us the invisible fine structure of substances—the way their actual atoms and molecules are arranged. It is a rather new branch of science, that owes more to Sir William Bragg, who wrote the introductory chapter of this book, than to any other man. The story of its applications, in pure physics, in the steel industry, in the wool trade, in general biology, is so fascinating that I shall try to tell it more in detail in a later chapter, when I come back to the interaction between pure and applied science. Here I will only say that it is allowing us with the eyes of the mind to see right inside the wool fibre and understand its intimate structure, and that this is helping the wool-chemists to a new understanding of their work, and opening up the way for all kinds of new tricks for the practical man to play on wool fibres. To take but two examples: in all probability this new knowledge will soon help to a final solution of the old problem of making unshrinkable woollens; and, since human hair differs only in detail from sheep's wool, it has already thrown light on some of the troublesome problems of permanent waving which afflict ladies' hairdressers.

But now I want to get on to a more general subject—about the relation of science not merely to textile processes, but to the textile industries themselves, looked at as part of the social and economic structure of the country. And here we find ourselves in what is really a very queer world of actions and interactions.

In the first place, science itself is changing the raw materials available for clothing. It has produced altogether new materials, like rayon. It has helped,

by means of breeding and selection and agricultural research, to produce more of the old materials, and in better qualities. The production of cotton has been pushed up until there is a glut, even of the best kinds, on the world's markets. In the chapter on food, I pointed out how the sheep-carrying capacity of this country could easily be doubled; and this concerns wool just as much as it does mutton. Recently, large-scale work on the improvement of flax has been begun, in Russia, this country, and elsewhere. There is no reason to doubt that the silk-producing capacity of silk-worms could be doubled by similar breeding work.

Now, all these different lines of work exert violent effects, actual or potential, on the various textile industries. The work on flax is bringing about a renaissance of linen, and so depressing the chances of cotton. Then, with all respect to the admirable qualities of modern artificial silk, most people would prefer real silk—if they could get it cheap; so any improvement in the genetic qualities of silkworms will improve the position of silk as against rayon in the struggle for markets Rayon itself has so far effected the most revolutionary change: not only has it provided a new cheap material which is a direct rival to other textiles (a process has been worked out for using whole cotton plants as the raw material for rayon products!), but it has also had a profound social influence. It has made it possible for girls with small incomes to make a brave bid for equal smartness with their more fortunate sisters in wealthier sections of society, which was impossible fifty years ago, and so has helped a great deal in the breaking down of class distinctions.

New machinery may also help in changing fashions. At Leicester, I saw a machine designed to make possible a new kind of stitch in the knitting of underwear. While the needles flick in and out at terrific speed, some of them are made to move sideways and transfer the thread to their neighbours! The fabric made in this way has not yet been put on the market; but when this happens, it will doubtless set a new fashion in underwear, as has already been done in the past by the introduction of other new types of stitch. So here we may say that the machine-designer sets the pace for fashion and comfort, and by so doing may give an advantage to one material over another.

While on the subject of fashion, let us also remember that it is now the fashion to wear much less clothing than our ancestors did But this is not merely fashion—it is also based on medical and physiological research, which tells us that it is healthier to wear light clothing, and so stimulate our skin to work at keeping us warm, than to muffle ourselves in layers of material and make no demands upon our skin. And naturally this reduction in the amount of clothing worn makes the struggle between the various textile industries more acute. Then there is the modern attitude of mind, which prefers quick changes of fashion to wearing qualities in dress. This, too, makes for violent fluctuation and more acute competition as between different fabrics and raw materials.

One important result of this competition is that much research is going on to find new uses for the different raw materials of clothing. With cotton, for instance, an enormous amount is used for incorporating with rubber to give wearing properties to motor tyres;

for this, specially strong fabric is needed. Then again, new types of fabric are demanded for aeroplane wings. Another new use for cotton is for insulating the parts of electrical machinery Here there is a growing demand. And doubtless the "creaseless" cotton I mentioned before will find all kinds of new fields to invade

Wool, too, claims a share in the manufacture of insulating material; and, if certain difficulties are got over, may be a dangerous rival to cotton in this field. Then there is rayon, which is finding an outlet in the manufacture of the wrapping material cellophane as well as in clothing—and so on. So, in a way, while science is making it possible for each of the separate industries involved in clothing to become more efficient, and to carry on in competition with its rivals, it is also aggravating that competition, and causing rapid and violent fluctuations in the industry as a whole.

Once more, in fact, we are brought up against economic and social problems—in this case against the problem of planning. Without the large-scale planning of industry, science is liable to cause as many difficulties as it relieves That is not a reason to cut down the rôle of science, but rather to enlarge it It means that we want scientific methods applied not only in the fields of technology and production, but also in those which affect the organization of particular industries, and indeed the economic life of the nation as a whole.

CHAPTER VI

SCIENCE AND HEALTH

PEOPLE are very prone to take things for granted in matters of health, both in regard to the treatment of disease and the day-to-day business of keeping well; and so you sometimes find a tendency to grumble at what science has *not* done in this supremely important field, instead of being thankful for what it *has* done.

And what it has done already is something pretty revolutionary. Let me remind you of some of its achievements. Before the nineteenth century there were no anæsthetics. People were often made drunk before an operation, and even then generally had to be held down while the sawing and cutting were going on. The pain and shock were so great that patients sometimes died of it.

With the progress of chemistry, chloroform was discovered, and other anæsthetics such as ether, laughing gas, and so on Their general introduction into surgical practice was undoubtedly one of the biggest steps ever taken to alleviate human suffering.

Later on came the local anæsthetics like cocaine and its relatives, which have done so much to rob a visit to the dentist of its terrors, and at the moment research is busy with a whole new batch of anæsthetic substances, which seem destined to rid anæsthesia of some of its present minor discomforts and dis-

advantages, and make major operations a less serious business.

But anæsthetics are no good if operations are dangerous for other reasons; and people often forget how intensely dangerous they were, right up to the middle of last century. With the huge increase in population, and the consequent growth of big towns and big hospitals, new possibilities were opened to those enemies of the human race—germs. And, as a result, infection and suppuration spread through hospitals like wild-fire. The slightest wound or even scratch often proved fatal, and the death-rate was appalling. Descriptions of the hospitals of those times are heart-rending, and almost incredible to-day

The reason for the terrible state of affairs was merely ignorance. Nobody knew what the enemy was. Germs had not been discovered It remained for the great French scientist Pasteur to prove their existence and to show that there was no such thing as their spontaneous generation, and then for the great English scientist and doctor Lister to apply Pasteur's ideas in medicine.

As a result of this new knowledge and the technique which has grown out of it, there is to-day less danger of infection as the result of an operation than there is from the little accidents of normal existence, and lives are being saved every day by wonderful operations which could not even have been dreamt of before the days of Pasteur and Lister.

Treatment, too, has been completely revolutionized. Gone are the days of bleeding as the universal remedy for all ills; gone, too, those when "a bottle of medicine" was all that medical science had to offer to a patient. Treatment with ultra-violet and other kinds of light,

special injections for all kinds of conditions, scientific dieting, remedial exercises based on scientific knowledge, prescriptions of ductless gland extracts and vitamins—these are some of the modern methods of treatment that simply were not available half a century ago.

Let me give one example of the advances in treatment which science has made possible. I went round some of the wards of the London Hospital, that gigantic institution with nearly a thousand beds, in company with the director of its research unit—or Medical Unit, as it is officially called. One of the wards I visited was for patients on special diets, which included, of course, sufferers from diabetes. One of these was a child of eight. He had come in on the Friday with hardly any flesh on his bones, and in a state verging on coma—the normal state of diabetics when the disease reaches a certain stage of seriousness By Monday he was cheerful and active in his mind, and had put on nine pounds—nine pounds in three days!

This sort of spectacular result is being achieved all the time with diabetics. The possibility of its achievement is due entirely to the patient researches of physiological science, which showed that diabetes was due to a disorder of the pancreas, and culminated in the discovery of insulin, the active chemical substance produced by the gland, which can be made from the pancreas of animals and used to remedy the patients' own deficiencies.

This brings me to the further question—what research is doing now to help us towards better health, and I might as well go on with the London Hospital

and its research unit. These research units are now a feature of many big hospitals The men working in them take their share of looking after the patients in the wards, but otherwise devote their time to laboratory research instead of teaching or private practice. The aim, of course, is to have as much scientific research as possible going on in close relation with the day-to-day needs of practical medicine There is generally also a clinical laboratory attached to a hospital, in which are made all the laborious routine tests and analyses (themselves made possible by past achievements of science) which are needed for proper diagnosis and treatment—chemical and biological analysis of blood and urine, tests for the presence of bacteria, and so on. Here, also, research is generally going on, and when a full-time regular research unit exists also, a fruitful liaison can be achieved

At the London, for instance, as well as fundamental work on kidney trouble, diabetes, anæmia, and other chronic diseases, research is in progress on new methods of estimating the amount of hæmoglobin in blood. Hæmoglobin is, of course, the stuff which not only gives blood its red colour, but confers on it its unique oxygen-carrying capacity; so it is very important to have an accurate measure of it This new apparatus, which works with the aid of a photo-electric cell, is more accurate and dependable than any of the old methods, some of which, it now appears, gave results that were often quite seriously out. The new apparatus will be a real help in many kinds of disease.

Parrot-disease, or psittacosis (which is merely the Greek for the same thing), is serious, and often fatal (you probably remember the scare about it not so long

ago), but luckily rare. However, it is interesting as being one of the diseases caused by what are known as filterable viruses, about which I shall have something to say later. Owing to there being research workers on the spot when a case of parrot disease came into the wards, research was started on the subject, and, as I was privileged to see with my own eyes down a microscope, has led to quite new discoveries concerning the cycle of growth and development which the virus goes through in the living body.

But I must not spend too long in one place I want to speak also of the work that is going on in laboratories of pure science, remote from hospitals and patients, and yet with a bearing on our health.

I will give you one excellent example of the way in which pure research, which at first sight seems altogether useless and impractical, may link up with extremely practical results. When I have occasion to go to Cambridge, I generally try to pay a visit to the Strangeways Research Laboratory to see what new results my various friends there are getting. The Laboratory in its present enlarged state is a memorial to Dr. Strangeways, who for some years carried out there his pioneer work on tissue-culture—that is to say, the cultivation of fragments of living tissue outside the body.

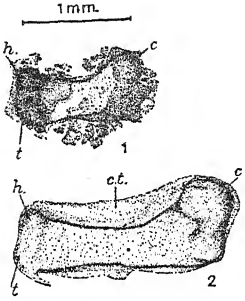
As most people know, the technique of this method has now reached a high pitch, and has enabled us to prove a number of interesting general facts, such as the immortality of tissue cells. The tissues of a fowl, for instance, die because of something concerned with their organization into a body: when cultured outside the body, they can go on growing apparently

indefinitely, and certainly for much longer than they would have if left in the hen.

At the Strangeways there has been developed a rather new line—of cultivating the early rudiments of single organs taken out of embryo chicks and seeing what will happen to them. They have, it is found, an extraordinary power of carrying on with their development on their own For instance, the fragment of tissue in the centre of the thigh-region of a very young chick embryo will not only turn into cartilage and then into bone just as it would have if left in its natural place, but will turn quite definitely into a thigh-bone.

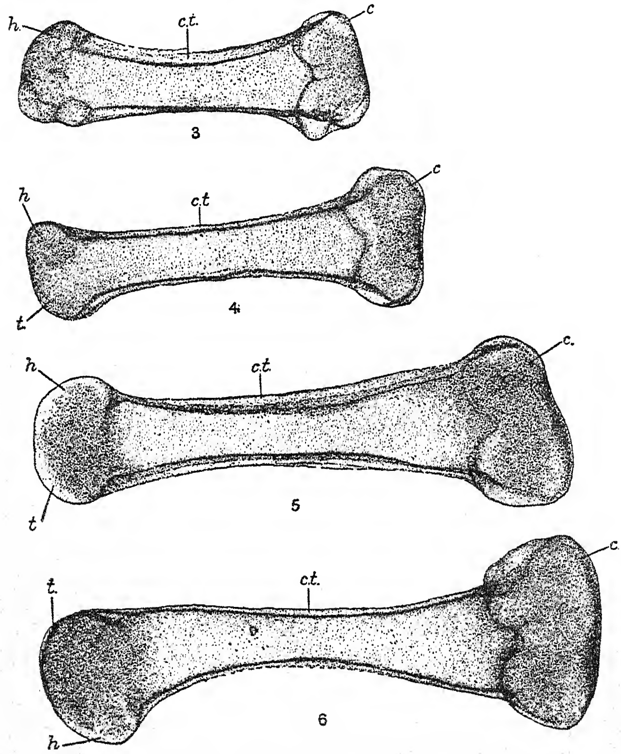
This suggested studying the machinery of bone-formation, by altering the chemical composition of the fluid in which such fragments were kept. This was done in conjunction with a research worker at the Lister Institute in Chelsea And, to cut a long story short, the experiments have helped us to understand the means by which lime and phosphorus are built up into normal bone; and this, in turn, is throwing light on the widespread disease rickets (from some degree of which over half the infants of this country are in all probability at this moment suffering), and on the whole question of how to promote full health and growth by means of extra vitamins

Then let me give an example of research which is still largely in the phase of pure science—the work which is going on all over the world in laboratories of physiology, chemistry, zoology, and in clinical wards too, on that extraordinary organ, the pituitary gland. We cannot yet see just where all this work is going to help in relation to human health; but for any one with



Fundamental biological research. The thigh-bones of $5\frac{1}{2}$-day embryo chicks were dissected out, placed in a drop of sterilized nutritive fluid, and allowed to grow. 1, immediately after removal; 2–6, after 3, 9, 15, 21, and 27 days' growth in artificial culture. The bones develop just as they would have if left in the body of the chick. (*See* p. 89.)

[*After Fell and Robinson. By courtesy of the Biochemical Journal.*



any imagination at all the possibilities opened up by it are almost awe-inspiring.

The human pituitary is quite a small organ—about the size of a hazel-nut—attached to the base of the brain It is found in all backboned animals, and develops in a very queer way out of two parts, one an ingrowth from the roof of the mouth, the other a downgrowth from the floor of the brain

Most ductless glands seem to have one or two functions only; but as research continues, the pituitary is being revealed as a kind of master-gland, with a quite extraordinary number of activities to its credit. With the aid of one or other of the various chemical substances which it secretes, it looks after growth; it helps the muscles of the womb to contract in child-birth; it regulates the amount of water in the body; it stimulates the thyroid gland to full growth and normal activity, it is a sort of opposite number to the pancreas in regulating the storage and utilization of foodstuffs, it is responsible for the rate at which the sex-organs come to maturity, and it controls the growth and liberation of eggs from the ovary in accordance with a regular cycle. It is also responsible in some way for the maintenance of the sex instincts, and, it seems, for the onset of old age and senility.

If we include other kinds of animals than man and his fellow-mammals, we find it controlling the secretion of "pigeon's milk" by doves and pigeons, responsible for change of colour in frogs and newts, helping in the transformation of tadpoles into frogs; and bringing on the hibernation of creatures which go into a winter sleep!

Three hundred years ago, Descartes, that great

French intellect, assigned to the pineal gland on the top of the brain the honour of being the seat of the human soul. He would have been much nearer the mark if he had suggested the pituitary gland below the brain! It is, of course, obvious from modern biological fact that there can be no particular organ which is "the seat of the soul," but the pituitary probably has more to do with human temperament and personality than any other single organ.

Perhaps some of my readers will be asking what all this has to do with health? But the answer, I think, is pretty obvious. Let me take a parallel case from another gland, where history has provided the answer. About half a century ago, Minkowski, in the course of some researches on the way fats were used in the body, tried the effect of cutting out an animal's pancreas. To his surprise, the animal developed the symptoms of that well-known and terrible human disease diabetes, which I mentioned earlier in this chapter. Fired by this observation, many workers began studying the relation between the pancreas and diabetes. It took about a third of a century before those studies bore fruit—in the discovery and preparation of insulin, the internal secretion of the normal pancreas. As a result, the diabetic patient to-day can live an almost normal life, instead of being condemned to complete invalidism and probable death.

This research concerned a single substance. The pituitary produces a dozen or more substances of at least equal importance to the workings of our bodily and mental machinery. Research is now more active than fifty years ago: in perhaps a quarter of a century this work will be bearing its fruits. We cannot be sure

exactly what they will be, but they are bound to be important. A more active old age, and perhaps an extension of the average span of life, better treatment for diabetes and other diseases concerned with the way our bodies utilize food; wholly new and improved methods of birth-control, some real control over the mysterious phenomena of growth—these are just a few of the ways in which we can be pretty sure these researches on a single gland are going to link up with the health of our children and grandchildren

Then I suppose my readers will expect me to say something about cancer—and quite rightly, too, since cancer is in many ways the most sinister disease.

Sir James Jeans not very long ago wrote a book *The Mysterious Universe*. Among the various mysteries which he did *not* touch upon was this horrible mystery of cancer—the cells of our own bodies rebelling against us, torturing us, and killing us. The theological conclusion of his book was that God, whatever else he might be, must be a mathematician. If he had carefully considered the mystery of cancer, he might have been driven to the theological conclusion that God found an interest in meaningless cruelty. But this is not the place for theological speculation. Let me come back to the hard facts of cancer. The work in cancer research has not yet discovered the fundamental cause of cancer, or given us a universal cure. None the less, it has led to real advances. To take only the last quarter of a century, we have in that time seen the experimental production of cancer by means of various substances, of which tar is the best investigated. This has led on to further studies, which have shown that only certain of the substances

derived from tar will produce cancer, and that these are all of the same general chemical structure. Extremely detailed chemical work is now in progress which may have a good deal to tell us in the near future.

Then a quite different line of advance is due to the German scientist Warburg, who showed that cancer cells have a different chemical behaviour from ordinary cells in respect of that most fundamental process of life, breathing. In getting the energy for their vital processes, they are much more independent of oxygen than are normal cells. This explains a number of the characteristics of cancer cells, such as their ability to grow and penetrate into other tissues; and perhaps eventually this fact will be linked up with the facts of cancer-production by tar, and we shall find that this change is what we should expect when the cancer-producing substances from tar are thrown into the crucible of the living body.

Finally, there is the discovery, first made in America, of the fact that certain malignant tumours of fowls could be propagated in other fowls, not merely by grafting a bit of them, but also by means of the clear fluid, entirely free of cells, which comes through when a chopped-up mass of tumour is passed through a filter fine enough to stop the passage of all visible particles. This has led to the belief that in these tumours at least, and perhaps in all, some sort of active living agent, like a virus, is the true cause of the diseased condition. There remain many difficulties in this view; but at any rate we have a fundamental new fact—namely, that in some cancerous growths something or other is produced which is invisibly small, and yet is able to start the same kind of growth again in another

animal. And quite recently two of the new lines of work have been linked up by the discovery that malignant growths can be experimentally produced in fowls by tar, and that in some cases at least these contain the active cancer-producing agent which can be filtered off. So at the moment, you see, the cancer problem is rather like the situation half-way through a detective story—a number of exciting and obviously important clues have come to light. they are being eagerly followed up, both by the official detectives, so to speak, working in cancer research laboratories, and by the unofficial sleuths in biological and chemical laboratories: and we feel that the climax of the plot cannot be long delayed, even if we are still unable to spot the murderer.

Meanwhile, let us not forget that on the purely curative side, thanks to radium, improved diagnosis, better surgical technique, and so on, the percentage of cases which can be cured has gone up quite considerably. There is one proviso—that they should ask medical advice as early as possible. Half the tragedies of cancer occur because sufferers put off consulting a doctor until too late.

The filterable tumours of birds link up with another very fascinating line of research which of late years has been getting more and more important—research on viruses and virus disease. I have already mentioned Pasteur's discovery of bacteria or "germs" Every one knows now that many diseases owe their origin to different kinds of these visible living creatures which invade the body and live upon and poison the tissues. Tuberculosis, typhoid fever, and diphtheria are three well-known diseases caused by bacteria.

This was of course one of the greatest steps ever

made in medicine—and indeed in general biology; but for a time people were inclined to think it an even greater step than it was, and to believe that *all* infectious diseases were caused by bacteria. Gradually, however, the list of diseases in which the most diligent search failed to reveal any such visible cause became quite a long one. It includes such dangerous diseases as yellow fever, sleepy sickness, smallpox, and influenza, such everyday complaints as measles, mumps, and our friend the common cold. In animals, there are foot-and-mouth disease of cattle, and distemper of dogs. In plants, many very destructive diseases, such as wilt disease of tobacco and mosaic disease of potatoes and other plants, fall into the same category.

Modern research has shown that these, too, are caused by specific agents, which seem to be alive like bacteria, but differ from them in not being capable of being cultivated apart from the living tissues which they attack, and in being so small (all except one or two) as to be beyond the range of the most powerful microscope.

They have been isolated by the same methods of filtration I spoke of apropos of the filterable fowl tumours; and from the size of the pores of the filters we can tell the size of the disease-producing particles. Besides this, of late years some of them have been rendered visible by photographing them with ultra-violet light. Their size, as determined by these methods, ranges between 5 and 250 $\mu\mu$—and a $\mu\mu$ (pronounced *mew-mew*) is a unit measuring about 1/25-millionth part of an inch. Bacteria, on the other hand, begin at about 250 $\mu\mu$ and range up to ten and twenty times as big.

These disease-producers are generally called viruses;

and of late years, thanks to new methods, we are at last getting to grips with these invisible enemies, as during last century we got to grips with visible disease germs.

This, by the way, is a good place to bring up the vexed question of experiments on animals.

Of course, I know, and my readers know, that there are those who argue—and argue sincerely—that experiments on animals should be prohibited—that they are cruel and unnecessary. For the scientist, however, it is hardly a vexed question, for if such experiments were prohibited, he would simply have to shut up shop in the branches of science which bear on human health . without experiment there can be no real advance, and animal experiment is often the only method of experiment available. This is pre-eminently the case with virus diseases. When a disease is caused by something which is too small to see, and which you cannot grow in broth or on jelly or any artificial medium, the only way you can get hold of it for controlled study is to pass it from one animal's body to another.

By such means the immunity conferred by one attack of disease has been studied, with extremely encouraging results. For instance, a completely successful method of treating distemper in dogs has been worked out in this country; and similar research has been going on with that terrible human disease, yellow fever, and now we are on the verge of being able to inoculate against it beforehand. The work on yellow fever would have been impossible but for experiments on mice and monkeys; and that on distemper—a gift of health to the dog world—without experiments on dogs and ferrets.

Animal experiment is also absolutely necessary in

another branch of medical science—standardization; but I shall have to leave this subject until I deal with the international aspects of science. Here I will only say that without standardization we would not dare to use such wonderful treatments as antitoxin for diphtheria, insulin for diabetes, or salvarsan for syphilis, since you must have just the right dose—too little is useless, too much is dangerous. And standardization, in the present state of our knowledge, can only be achieved by the use of experimental animals. I wonder how many anti-vivisectionists would refuse such treatments for themselves or their children?

I could go on with examples of what research is doing and might do, but I must devote what space is left to another aspect of the question. With all the improvement in the past and all the gifts of science in the present, it remains an obvious and lamentable fact that the standard of health is very much below what it might be. For one thing, acute disease of many kinds is still rampant. Our descendants will doubtless look back on our civilization, with its widespread tuberculosis and syphilis, its high cancer death-rate, its epidemics of influenza, with the same kind of tolerant pity that we think of that of our ancestors, burdened with typhus, plague, malaria, and smallpox. Then, for another thing, the glowing, radiant state of really full health is all too rare: probably not one among a thousand of our city populations has it.

To what is due this gap between the possible and the actual? It is due, for one thing, to the complexity of the human body and its workings, and the consequent wide extent of our ignorance. Few but professional biologists realize the almost appalling degree of this

complexity. But when all allowance has been made for this, there is a glaring difference between what we could do with our existing knowledge and the state of affairs which actually exists

Preventable causes, such as overcrowding, insanitary houses, and lack of facilities for open-air recreation, account for a great deal of our tuberculosis. If we were to treat the venereal disease problem primarily as one of hygiene, as we do with scarlet fever or diphtheria, and not bring morals into the question of treating and especially of preventing it, we could reduce the amount of it to a fraction of its present figure. But perhaps the most striking example is in the field of diet The research of the last dozen years has really solved the main scientific problems of diet, so that we now know the essential facts about all the more important of what are called the accessory food factors—the vitamins and the mineral salts—which are necessary for health, proper growth, and resistance to disease, over and above the food needed for the general requirements of the body in respect of fuel and wear-and-tear.

And we know that a large section of the population is suffering from at least a slight deficiency in one or other of these food-factors, and therefore falls short (in energy, physique, and freedom from sickness) of its birth-right of possible health We know this from physical measurements, such as the lower average stature and weight of children from poor neighbourhoods. We know it from the astonishing prevalence of mild disease, such as slight degrees of rickets. We know it from scientific analysis and experiment, as when a sample of the diets of poor families is taken and analysed and found to be at or below the danger-line

for certain substances—and, when given to animals such as rats, leads to widespread chronic disease and heavy mortality.

It is safe to say that a benevolent dictator could double the level of general health merely by means of applying what is now known about diet. The reason for the present state of things is partly public ignorance, but is largely sheer poverty. On the whole, the right kind of foodstuffs cost more, and it is all but impossible for many people to eat healthily on the wages or the unemployment allowance which they receive: both in quantity and still more in quality, their food, in present conditions, is bound to be near the danger-line. On the other hand, it would be possible, at no great expense, to supplement inadequate diet by adding the vitamins and mineral salts that are likely to be deficient; they might, for instance, be put in bread. This is where the benevolent dictator would come in. At present it seems to be nobody's business to take the necessary steps.[1]

Under our present system we have to rely on other means to get things done—public health administration, school medical service, and the slow education of the public and those who supply its needs I have not space to deal with all the questions that spring up directly one begins to think of public health adminis-

[1] Since this chapter was written, a step in this direction has been taken, by the proposal to provide milk, perhaps the most important single source of accessory food-factors, for school-children at well below market rates It may be that the next fifty years will see the provision of an adequate diet and adequate housing regarded as basic social services, to be provided out of community funds, just as happened, in spite of great opposition, with elementary education, the police service, and water-supply during the nineteenth century.

tration Should the State maintain the hospitals, as is done in most other countries? Should a health policy aim at a State medical service, with reduction or abolition of private practice, as is roughly the state of affairs in Russia?

These are difficult questions, but well worth thinking about. We should bear in mind the existence of the school medical service. The recognition that a State-controlled system of education could not concern itself only with the mind, but, if it was to get good results, had to deal with the body too, was a great step forward in our national health policy

But, meanwhile, the education of the public at large remains as a necessity if we are to continue raising the level of health in the country This is linked up with a number of other knotty problems. For instance, should the advertising of patent medicines be forbidden, or regulated in some way? Should the complete formula of every such medicine, with a statement by some public health authority as to the known effects of the various ingredients, be printed on every bottle or box? There are many pros and cons: again, it is well worth discussion.

What we need most of all, perhaps, is some policy and organization for positive health, not merely an organization and a policy centring round disease. One of the most interesting experiments in this direction is the Pioneer Health Centre at Peckham, with the directors of which I have had several talks in the last few years. This, if you want to sum it up in a phrase, is a Health Club. Families belong at so much a week. Every member of the family gets an overhaul every so often—the more often the younger they are. It is a really

thorough overhaul, using all the resources of modern physiology, for the directors (who are, of course, themselves qualified doctors) have found that by these means you can not only detect but correct slight tendencies to bad health (such as rheumatic tendencies in children) which could not have been got rid of, in the great majority of cases, if they had gone on to the stage when they would have been detected by an ordinary routine medical examination.

People with any medical symptoms of disease are referred to their regular medical advisers, who prescribe for them in the ordinary way. But the speciality of the place is the way it deals with the side of life that is not usually considered to have a relation to medicine at all. The directors, after finding out all they can about the temperament, inclinations, and home life of their members, prescribe what they call "activities" for them. The activity may be something physical like swimming or boxing; it may be intellectual, like study (special rooms are provided for those who cannot get the chance of quiet study at home, and someone is on hand to answer questions and give guidance as to reading); it may be membership of the dramatic club or the discussion group. The point is that the activity is medically prescribed, just as a bottle of medicine is prescribed, and that the member of the health club (I do not like to call him the patient) pays so much a week for the activity concerned, just as he would pay for the medicine. Great attention is also paid to the psychological side, especially to the personal relations of members with the rest of their family; and as everything is done on a friendly basis, as part of the obligations of membership, the work does not come up

against the opposition which might greet it if carried out in a routine official way

By such means, much progress has been made in raising the health of the members. As one of the directors said to me, everyone interested in health aims at conferring on the body a full stature, a good carriage, and a right gait "We feel," he said, "that the same should apply to the mind We aim at opening up the possibility of full stature to the growing mind, of conferring on it a healthy carriage, instead of the limp slouch or the cramping tension which too often characterizes it, and of allowing it to find its own right gait and speed, instead of forcing it or holding it back. This is not only good for the mind, but, as body and mind are merely aspects of the single organism, it is good for the body too"

It is true that if we could see minds as we see bodies, we should be horror-struck at the stunted dwarfs, the cripples, the gnarled, distorted mental creatures that would be revealed to us on every side; and this scheme of the Pioneer Health Centre is a most valuable and interesting one It is not yet four years old. The directors plan to continue for a few more years, to see whether they really are on the right lines and if the scheme can be maintained on a self-supporting basis, and then, they hope, something will be done to start similar centres elsewhere.

But I must bring this chapter to an end I hope I have made certain things clear—notably that without science in the past, the great historical advances of medicine could never have been made; that without science in the present, the medical and health system of the country would just collapse; and that without science

in the future, there will remain great tracts of ignorance about the human body and its disorders and treatments, where medicine can only grope instead of acting with certainty and knowledge.

I hope I have also made clear that, however great our scientific knowledge, there are all kinds of obstacles and barriers to its being properly applied—poverty, vested interests (in the purveying of food and housing, for instance), religious prejudices (such as those which try to prevent the spread of reasonable birth-control knowledge), public ignorance and apathy, lack of social and economic planning, and so on, and that to get it across, you need a very definite positive health policy, and great energy and determination in carrying it out.

CHAPTER VII

SCIENCE AND COMMUNICATIONS

I FOUND it extremely difficult to work out any coherent plan for this chapter, on science and communications Communications cover such a multitude of different things—from aeroplanes to Zeppelins, from roads and railways to telephones and telepathy, from languages and letters to cables and canals, from different sources of power for propulsion like coal, oil, and electricity, to different means of disseminating information like books, wireless, and the cinema And not only that, but science has been busy in so many ways, laying the foundations for so many applications, that the effects on human life are bewildering both in their magnitude, their number, and their rate.

So I thought that in this case I would leave out most of the technical scientific side of things, and confine myself more to the applications, rambling over the field to show the different ways, sometimes expected, sometimes odd and very unexpected, in which one advance may act, react, or interact on others.

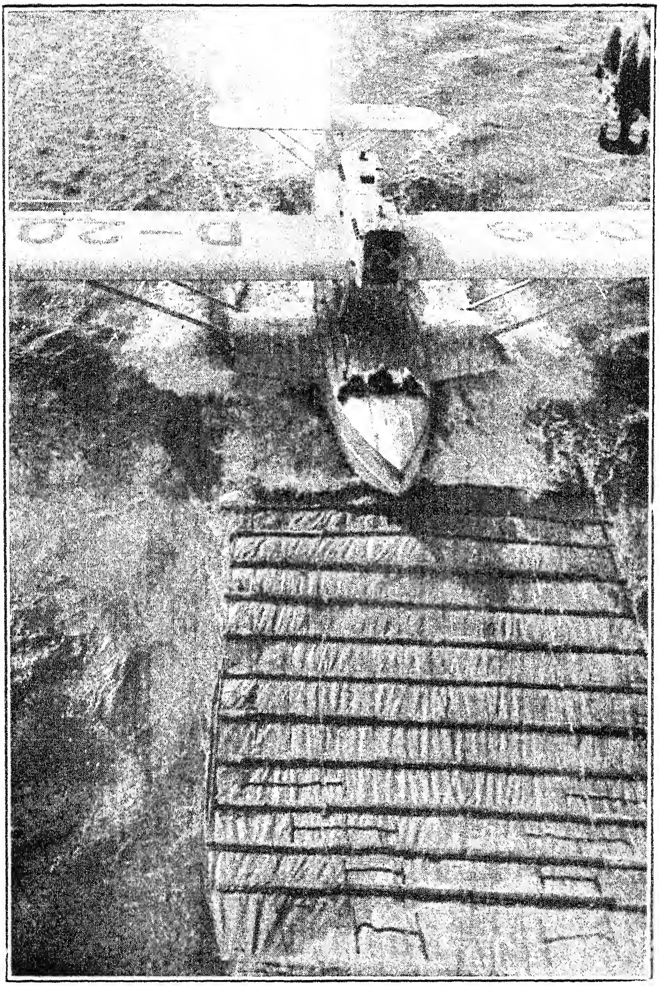
The first and most elementary fact about communications is that they changed hardly at all for about two thousand years, and then were suddenly plunged into a period of revolutionary change, which is still in full blast, by the application of human inventiveness

and, in an ever-increasing proportion as time went on, of science

Until the end of the eighteenth century, the roads of England were no better than in Roman times. One of the Georges, travelling from Windsor to London, got stuck and had to leave his royal coach in the mud. Within living memory, pack-animals were still used in some parts of England as the main means of transport. Shipping showed rather more improvement; but it was not until the introduction of steam power and iron hulls that the big change came. The speed at which information could be transmitted did not alter materially until the introduction of railways, and not very materially until the time of the electric telegraph. Even the original telegraph, the semaphore system by which, during the Napoleonic Wars, messages were sent from the south coast to London in about a minute, is paralleled by the drum-signalling of many quite primitive peoples. The one big alteration that came in before the industrial era was in regard to the communication of ideas. Here, the invention of printing, which was really the first example of mass-production methods, did really effect a revolutionary change several centuries earlier.

Now let us take a few threads and see where they run and how they pull on other threads. I suppose most people would agree that the internal-combustion engine has effected the biggest single change in transport after the introduction of steam, since it brought into being both the motor-car and the aeroplane, not to mention motor-ships

The idea of using an explosion of gas or vapour to drive an engine grew directly out of fundamental



L.E.A.

Post-war changes in transport: a seaplane landing to re-fuel on a floating platform in mid-Atlantic. (*See* pp. 106, 104.)

Post-war changes in transport: an autogiro in flight. (*See* pp. 106,

scientific researches on gases and on the nature of combustion. Proposals for engines of this type were actually made and patented as early as 1794, but no workable type was produced, even of a stationary engine, until after the middle of last century, and vehicles with internal-combustion engines have less than fifty years' history. After an infancy in which they were jeered at, motors became a luxury, and then, largely thanks to Mr Ford, a necessity of everyday convenience and pleasure, whether in the form of privately-owned cars or motor-buses. Largely since the War, motor vehicles have claimed an increasing share of goods transport

All this is an outcome of the work of the scientific pioneers in the eighteenth century, who found out how to make different pure gases, and discovered that some of them would explode violently if ignited in the presence of air. Its consequences are varied and enormous.

For one thing, it has done a great deal, especially in the United States, in breaking down conventions and making for greater freedom between young people of opposite sexes—a ferment of the social revolution of our age. Then it has made new demands upon the road. Those of you who are middle-aged can remember the funny business of preparing for a ride in a car in pre-war days, by swathing yourselves in veils and dust-coats against the horrible clouds of dust That simply could not continue; and the demand for dust-suppression has turned our roads from white to black (though concrete is turning some of them white again).

Similarly, there has been a demand on the roads for safety from skidding, for the straightening out of

bends, for proper banking, for ability to stand up to much heavier and speedier traffic.

A good deal of experiment was done on this, which has eventually developed into a wide and well-organized programme of research at the Road Research Laboratory, now under the Department of Scientific and Industrial Research, at Harmondsworth. Motorists on the Colnbrook by-pass will probably recollect a spot where there are two sections of road side by side. One of these is an experimental road, which is used to test out different types of road materials and construction under practical conditions. The laboratory is close by.

All sorts of problems are being tackled here, but as the station is still very young, little has reached the full practical stage. I will mention only two. For one thing, the workers at the Station are busy with the design of a machine which will really measure road-wear, but they must have something which in a few days or weeks will produce on an experimental road the same sort of effect that actual traffic will produce on a real road in the course of years.

Then there is the whole problem of accidents: over six thousand fatal ones every year in this country. Of these a large number are due to skidding; and every motorist knows what a difference there is between different road surfaces as regards liability to skid. A machine has now been designed to express this liability in quantitative terms. It consists of a side-car combination which can be made to drag along at an angle, and in which the force needed for such a drag can be recorded. With this, samples of different surfaces can be quickly tested out and compared as regards what we may call their skiddability. In this and many other

directions, great improvements in road construction are being effected

But all this activity on the road has stimulated the railways to activity on their side. To take one example, the L M S has now large scientific laboratories, where the most varied kinds of research are carried out. The work is in charge of a distinguished academic scientist, whom they invited from one of the older Universities a few years back

Here, too, let me give a couple of examples Every unnecessary expenditure must, of course, be rigorously excluded. Obviously, one of the biggest items of expenditure by a railway is coal—the L M.S., for instance, buys nearly £5 million worth of coal a year! So if you can make the same amount of coal drive a train further, you are effecting a big economy. Air resistance is one of the big factors, especially at high speeds, so the L.M S. arranged with the National Physical Laboratory to have a model of the Royal Scot, complete with tender and six coaches, tested in the wind tunnels (which were built primarily for research on aeroplanes, but served equally well for this piece of work). The tests showed that the Royal Scot, at sixty miles an hour, without any head-wind, was using up about four hundred horse-power—over a quarter of the total power it was expending—in overcoming air-resistance. The tests also showed the exact share of the engine, tender, and coaches in producing the air-resistance. This work was, of course, the starting point for new designs aimed at reducing this terrific amount of resistance by proper stream-lining.

The research to be undertaken by a railway is varied —the L.M.S., among other items, is busy with work

on steel, on copper for fireboxes, on water-softening processes to prevent scale in boilers, and on the best methods of painting. You probably would not think that painting railway carriages would offer much scope for science, but by careful research they have arrived at a new paint which will last a good deal longer, and, by prolonging the time a carriage can be in use between its periodic visits to the repair shops, will effect savings that seem destined to be in the neighbourhood of a hundred thousand pounds a year!

My general point is that much of this research, I feel pretty sure, would not be going on if it had not been for the competition of road transport. As a result of this, the railways went through a bad period, from which they emerged with a determination to do something big to regain some of their lost ground. So we have intensive research, widespread electrification, longer week-ends, cheaper return tickets, and all sorts of facilities which the passengers of an earlier era did not dream of.

Some of these reactions of the railways to the roads, by the way, have had striking further effects. It happens that the Southern Railway has done more towards electrification near London than any other of the big companies. As a result, there has been more building development on this side than on the east or north, for instance. And this, of course, has brought its own problem of road communication

Among the demands made on the road system by the growth of motor transport is that for new roads as outlets from cities—a demand which has given us roads like the Great North Road, the Kingston by-pass, and so on. The growth of these new arterial roads itself

made a demand upon the scientific spirit, but one which, alas, has not been satisfied.

The laying out of the roads themselves was done scientifically enough. The obvious corollary to this planning of the line of the new road would have been the planning of the area on either side of the road. But what has actually happened? Instead of the road being kept to its real function as an outlet, new suburbs, almost all in ribbon development, have been allowed to parasitize the road and turn it into a supplier of local transport needs, instead of an artery straight from the heart of the city to the country. The only people who have profited are the owners of the land on either side. The dwellers in the new houses have a dangerous and noisy stream of traffic flowing past them, and the arterial roads are getting so congested that in some places they themselves might with advantage be by-passed! And this leaves out the blatant ugliness of the business Contrast this with a road like the Northern Parkway out of New York, which has been properly designed so that it does remain arterial, and also remains beautiful, and the Englishman feels ashamed at the stupidity of what has happened in his own country.

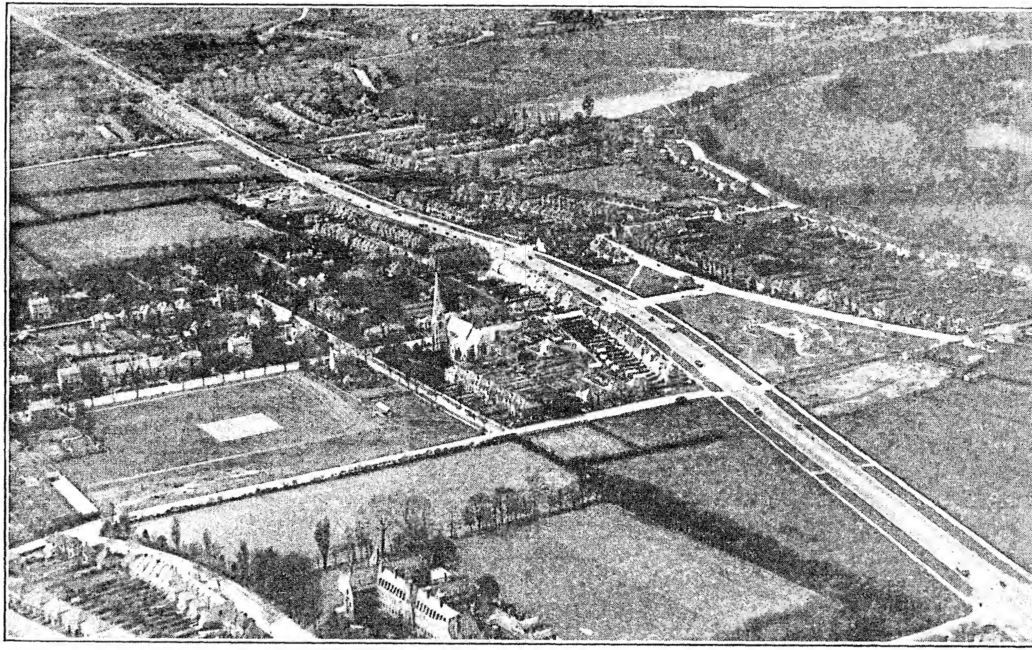
This leads on to another problem—the need for a scientific organization of transport systems, as well as the scientific improvement of the mechanical means of transport. As an example of what the scientific method, in the shape of planning, can do in these matters, we need not go further afield than London, with its new gigantic Passenger Transport Board, which unifies under a single planned control all the undertakings concerned with moving masses of people

about—buses, tubes, and trams—over the whole London area. And we may contrast this with the state of affairs in the Manchester area, where there are nine separately-administered undertakings, all running their own transport services. That means nine central offices, nine reserves of trams and buses, nine emergency staffs, nine repair organizations, nine workshops, all in the one region The unnecessary duplication is enormous.

There, however, as happened in London, the logic of the situation is forcing things to a conclusion, and a move is on foot to amalgamate all the nine in a single board.

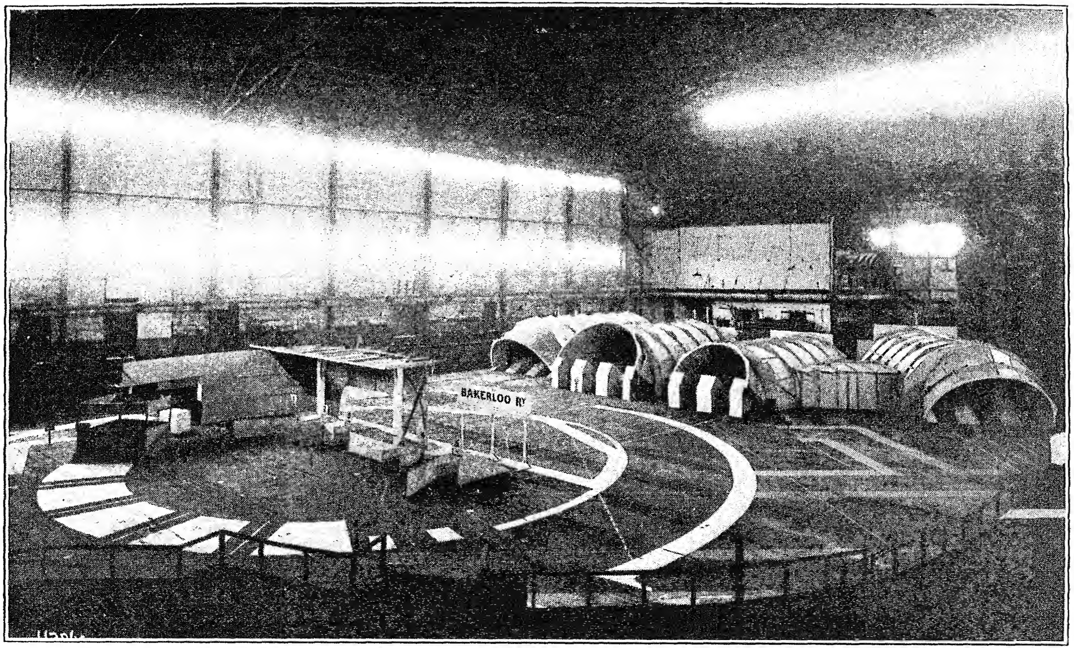
I had a talk with the Chief Engineer of the London Transport Board at the head offices over St. James's Park Station, and he told me some of the scientific research work which they were carrying out. A great deal of it, it is good to note, is directed towards the comfort of the passenger. Elaborate studies of noise are being made with a new instrument, the audiometer, which measures noise pretty nearly in terms of its loudness to the hearer, instead of, as with many sound-measuring instruments, in terms of the amount of energy, in the scientific sense, which goes to make it.

Does most of the noise in a tube-train come from reverberation on the walls of the tunnel? Is it made mostly by the wheels or the body-work? Does it come through the windows or the floor? What is the effect of lining tunnels with absorbent material like asbestos (it must, of course, be fireproof as well as sound-absorbent)? And so on. Accurate answers to these questions are being got by scientific measurement, and less noisy trains will be the result.



Aerofilms Ltd.

A planned road in an unplanned countryside. Ribbon development along the Great West Road, with Heston airport in the distance. (*See* p. 111.)



Topical Press.

Scientific planning in the field of transport. Full-scale models of parts of the Piccadilly Tube Station (from different levels of the actual station), erected at Earl's Court. (*See* p. 113.)

Then they are measuring the amount of vibration. I saw a machine for doing this, and the record it had made of a journey over a few miles of the underground system The record showed the position and extent of every vertical bump and every sideways sway, and also the rate at which acceleration and deceleration—getting to speed from stop and back again—was achieved. Another machine measured the actual tiny movements of a rail as a train goes over it All this is leading to various improvements in smooth running. Then there is work on ventilation, which has led, on the new lines, to ventilating shafts being put between stations instead of in the stations, and so on.

Even the problem of getting people to and from the trains can be studied by the scientific method. When the new Piccadilly Station was projected, they had full-scale models of its different floors made in pasteboard; and, in consequence, were able to make numerous alterations that could not have been suggested from the mere study of plans and blue-prints. So here the research spirit has definitely saved the London public a certain amount of disagreeable jostling.

But with all the improvements that have been made, there are other causes outside the scope of even the most powerful transport board which have brought the traffic of our big cities into a not very happy state. The very advances of science which have made it theoretically possible to get quickly from place to place, have produced a congestion which is making that result more and more difficult of attainment.

Let me illustrate this by a little personal experience When I went to see the Chief Engineer, I motored the five miles from my house—and was quite badly held

up on five occasions. Once it was a string of horse-carts; once trams; once an intersection of two main arteries of traffic; once the road was up; and once it was a bad block at Piccadilly Circus. Here are at once five problems for discussion. One: horse-traffic is cheap for some purposes, but it slows down motor traffic; should it be totally or locally prohibited? Two: trams were the ideal conveyances in their day, but in modern conditions they slow down traffic and add to its dangers; shall we try to replace them, and if so, with buses, trolley-buses, or what? Three: you cannot help traffic intersections; but should you go to the large expense of having tunnels for all the traffic that wants to turn across the opposite-flowing stream, as they do in some American cities? Four: at present, you have to be perpetually taking the roads up and laying them down again for work on gas mains, sewers, water-pipes, electric lines; should there be service tunnels under all main roads, or how else are we to remedy the inconvenience? Five and finally: Piccadilly Circus brings up the whole question of town-planning. When the motor-age overtakes an old city, you are almost bound to get central congested spots. How are you going to prevent the congestion becoming acute? It is already so acute in some parts of London and New York that at certain times it is a good deal quicker to walk than to take a taxi.

But I must not stray too far. I would like to say that town-planning is, on one side, itself an application of science, and is becoming increasingly urgent as the result of other applications of science, such as improved transport facilities.

Meanwhile, curious things are happening as the result

of applied science, coupled with invention and human daring, invading the air I shall have more to say in a later chapter about the share of research in the technical development of aeroplanes: here I will stick to some of the results. This country has seen a certain defined sequence in the development of communications: first riding and pack animals; then wheeled animal transport on roads; then steam and railways; then the motor invasion of the roads; then the invasion of the fields and rough places by caterpillar tractors and the invasion of the air by airships and aeroplanes We have seen the better part of this sequence compressed into the space of a single generation

To-day, however, in some parts of the globe, the same sort of development is going on, but in reversed sequence. A year or so ago I met a German journalist who had just come back from a visit to Tadjikistan and other mountainous Asiatic regions of Soviet Russia. There, he told me, pack animals were up till quite recently almost the only means of transport. The first sign of progress in communications was the aeroplane; next came tractors for the fields; only after that did roads begin to be made and motor traffic to appear; while the horse-drawn wheeled vehicle showed up very little, and last of all!

The same sort of thing is occurring in many parts of Africa. The aeroplane need not bother much about marshes and jungle and steep hills; the roads and the railways come later. In Africa, too, it is a very moot point whether railways shall be built at all in certain districts, or whether good roads and good lorries and buses will not serve the needs of traffic better and more cheaply. Much of Africa remained undeveloped until

a date sufficiently long after the invention of the internal-combustion engine for this question to be put. Fifty years ago there was no such question—the railway was then the only possible solution. That is an interesting sidelight on the way scientific and technical progress links up with the accidents of history.

So far I have been talking about the applications of science to transport—all the devices which promote travel and getting about from place to place, and make for a more restless world. But while all this was happening, other scientific discoveries were being made, which, though they too were applied in the field of communications, on the whole worked in the opposite direction. I mean, of course, the discoveries which have made it possible for people to have the whole world brought before their eyes and ears at home, instead of their having to go out into the world. Printing and the daily press constitute one of the tendencies working in this direction; but perhaps even more important in the long run were two scientific discoveries of last century—the discovery of long ether waves and of the photo-electric properties of metals.

Let us take these in order. Hertz's discovery of the long ether waves was the first to exert practical effect in this sphere. Thanks to scientific pioneers like Sir Oliver Lodge, and brilliant inventors like Marconi, Hertz's discovery gave birth to a wholly new method of communication: a modern Ariel with a million voices—the wireless. Everyone knows the story of its development—from its first employment as an alternative to the cable system in sending Morse and similar messages; its widespread use to ensure the safety of ships; its technical improvement until it became

capable of transmitting music and the human voice without undue distortion; then the astonishing growth of broadcasting (some critics are apt to forget that broadcasting is a very young baby still—less than fifteen years old) This, of course, has been followed up with enormous improvements in transmission and reception; and recently the introduction of short-wave systems (which incidentally has been linked up with a great advance in our knowledge of what the upper layers of our earth's atmosphere are like) has made it possible to transmit all round the world with the expenditure of very little power.

In the early days, the wireless represented only a new way of doing an old thing—sending urgent messages very quickly for long distances. Its one new feature was that, as it did not depend on fixed channels of transmission like wires and cables, it could get the messages to and from places which otherwise could not be reached—ships are the most obvious example.

But in its later development it is doing something really new—bringing to the multitude the actual living voice of statesman and singer, teacher and preacher, instead of a mere printed account; allowing you to sit at home and enjoy concerts and entertainments which are taking place tens or hundreds of miles away.

But before pursuing this line of thought, let me go back to photo-electricity. This is the study of the electrical changes which go on in certain substances when light falls on them. The rare metal called selenium is the substance which shows these changes most strikingly: if light falls upon it, it changes its electrical resistance.

The photo-electric properties of metals have a great

many modern applications—I have already mentioned two or three, such as the accurate estimation of the amount of hæmoglobin in blood and of the efficiency of different laundering processes in getting rid of dirt in the wash. From our present angle, they are important as having been the original basis of television. All systems of television depend on the translation, by means of photo-electricity, of the different intensities of light and shade in different parts of a subject, into different intensities of electric current; and then, at the other end of the process, of the re-translation of these into light, to form a picture. Selenium cells were at first used; the photo-electric properties of the metal saw to it that the density of different parts of the electron stream varied with the intensity of the light.

Another great contribution of science to television is the cathode-ray oscillograph, which grew directly out of the researches of pure physicists on the curious things that happened when electric currents were passed through tubes containing highly rarefied gas. To-day some systems depend on the emission of a stream of electrons by a metal plate in a vacuum tube; but it would be impossible to mention here all the methods that are being tried out. It looks, however, as if the recent applications of science to the television problem are destined quite soon to bring about a radical improvement in efficiency and practicability. It really is on the cards now that television will eventually become as practicable as radio, though it is never likely to be as cheap.

And then, when people in their own houses can both see and hear what is going on in the world, sitting at home will really begin to be quite a rival to rushing

around. And when the films are coloured and stereoscopic as well as talkie, and perhaps have smell thrown in too, at least you will have less temptation to travel instead of going just as far as the nearest cinema-house.

So there are, rather surprisingly, these two opposing tendencies of progress in communications, one tending to the increase of wandering, the other to the quiet evening at home.

There are, however, other aspects of the matter than this merely physical one. Communications can unify the minds of people as well as transport their bodies. The United States, for instance, could not have a real national life but for the telegraph and other methods for the speedy transmission of news and ideas. Here again, modern applications of science are leading to wholly new developments.

If we want to take a peep into the future, we may, I think, regard it as pretty certain that a hundred years hence, telephony and television will be so perfected that if a statesman is prevented from coming from Washington or Pekin to Geneva, or whatever will then be the seat of the successor to our present League of Nations, he will be able to take part in the discussions almost as if he were in the room, both heard and seen by his colleagues on the Committee, and able himself to hear and see their reactions to his words. This will clearly simplify the problems of world government a great deal.

The telegraph and long-distance telephone have already wholly transformed the relation between generals and ambassadors and the authorities at home. Until after the middle of last century, the man on the spot had to show initiative and take responsibility in

the same way as a Cabinet Minister at home. To-day, he is at the end of a wire, and must all the time be taking either orders or advice

Then broadcasting has given statesmen enormous new powers. Look at the influence exerted through this channel in the last few months by Roosevelt and by Hitler. Broadcasting and the cinema have also brought new possibilities of propaganda, both in its bad and its good sense, and of education. The new vistas opened up in the vast areas of the globe still occupied mainly by people who cannot read is enormous —possibilities of intelligent co-operation with government, of improved agriculture, of better health, of recreation and culture.

So I could go on, if I had the space. But I must pass to another point. Although here, too, improved communications can link people together, they can also be employed to keep them apart. It is common knowledge that in certain parts of Europe, nationally-controlled broadcasting systems are being used for nationalist propaganda purposes. More and more powerful stations are being erected, to ensure the penetration of this propaganda to greater distances, or even to swamp or interfere with the broadcasts of neighbour nations.

Language is another example, so familiar that we are apt to forget about it. It is essentially an instrument of communication. But it can also become a badge of difference (as in the Shibboleth incident in the Bible); and to-day, with the spread of nationalist feeling, languages are more and more becoming organs of nationalism. To counteract this, we want a scientific study of the best means of getting world communication

by means of an international language, auxiliary to the national languages already in existence

So here, too, as in all the other fields I have discussed, the applications of science become entangled with politics and economics, both affecting them and being affected by them. The logic of improved transport and communications is a world-state, the fact of the existing world is its organization into competing sovereign national states. The logic and the fact are in violent conflict; and there the scientist must perforce leave the problem.

Before I end, I would like to suggest some ideas for discussion. Here is one The development of flying has made national boundaries, especially in Europe, look rather ridiculous; and all their frontier formalities, of passport, customs, and immigration regulations, are a drag on the efficiency of long-distance air journeys. Should the scientific method be applied in planning an internationalized world air service?

Here is another. We have seen that the development of broadcasting within the framework of sovereign national states has led in quite a number of cases to competition and rival propaganda over the ether—a wordy war in the air. Should we aim at a regulation of broadcasting power as we aim at a regulation of armaments? Going still further, we have in any case the radio over-riding national frontiers, and in short-wave transmission we are developing a method for broadcasting to the whole world simultaneously. Should we make the next logical move, of setting up an international commission to take measures for the introduction of a universal auxiliary language? And, if so, should this be an artificial language like Esperanto

BASIC ENGLISH

OPERATIONS 100 ETC.	THINGS — 400 General				THINGS — 200 Picturable		QUALITIES — 100 General	QUALITIES — 50 Opposites
COME	ACCOUNT	EDUCATION	METAL	SENSE	ANGLE	KNEE	ABLE	AWAKE
GET	ACT	EFFECT	MIDDLE	SERVANT	ANT	KNIFE	ACID	BAD
GIVE	ADDITION	END	MILK	SEX	APPLE	KNOT	ANGRY	BENT
GO	ADJUSTMENT	ERROR	MIND	SHADE	ARCH	LEAF	AUTOMATIC	BITTER
KEEP	ADVERTISEMENT	EVENT	MINE	SHAKE	ARM	LEG	BEAUTIFUL	BLUE
LET	AGREEMENT	EXAMPLE	MINUTE	SHAME	ARMY	LIBRARY	BLACK	CERTAIN
MAKE	AIR	EXCHANGE	MIST	SHOCK	BABY	LINE	BOILING	COLD
PUT	AMOUNT	EXISTENCE	MONEY	SIDE	BAG	LIP	BRIGHT	COMPLETE
SEEM	AMUSEMENT	EXPANSION	MONTH	SIGN	BALL	LOCK	BROKEN	CRUEL
TAKE	ANIMAL	EXPERIENCE	MORNING	SILK	BAND	MAP	BROWN	DARK
BE	ANSWER	EXPERT	MOTHER	SILVER	BASIN	MATCH	CHEAP	DEAD
DO	APPARATUS	FACT	MOTION	SISTER	BASKET	MONKEY	CHEMICAL	DEAR
HAVE	APPROVAL	FALL	MOUNTAIN	SIZE	BATH	MOON	CHIEF	DELICATE
SAY	ARGUMENT	FAMILY	MOVE	SKY	BED	MOUTH	CLEAN	DIFFERENT
SEE	ART	FATHER	MUSIC	SLEEP	BEE	MUSCLE	CLEAR	DIRTY
SEND	ATTACK	FEAR	NAME	SLIP	BELL	NAIL	COMMON	DRY
MAY	ATTEMPT	FEELING	NATION	SLOPE	BERRY	NECK	COMPLEX	FALSE
WILL	ATTENTION	FICTION	NEED	SMASH	BIRD	NEEDLE	CONSCIOUS	FEEBLE
ABOUT	ATTRACTION	FIELD	NEWS	SMELL	BLADE	NERVE	CUT	FEMALE
ACROSS	AUTHORITY	FIGHT	NIGHT	SMILE	BOARD	NET	DEEP	FOOLISH
AFTER	BACK	FIRE	NOISE	SMOKE	BOAT	NOSE	DEPENDENT	FUTURE
AGAINST	BALANCE	FLAME	NOTE	SNEEZE	BONE	NUT	EARLY	GREEN
AMONG	BASE	FLIGHT	NUMBER	SNOW	BOOK	OFFICE	ELASTIC	ILL
AT	BEHAVIOUR	FLOWER	OBSERVATION	SOAP	BOOT	ORANGE	ELECTRIC	LAST
BEFORE	BELIEF	FOLD	OFFER	SOCIETY	BOTTLE	OVEN	EQUAL	LATE
BETWEEN	BIRTH	FOOD	OIL	SON	BOX	PARCEL	FAT	LEFT
BY	BIT	FORCE	OPERATION	SONG	BOY	PEN	FERTILE	LOOSE
DOWN	BITE	FORM	OPINION	SORT	BRAIN	PENCIL	FIRST	LOUD
FROM	BLOOD	FRIEND	ORDER	SOUND	BRAKE	PICTURE	FIXED	LOW
IN	BLOW	FRONT	ORGANIZATION	SOUP	BRANCH	PIG	FLAT	MIXED
OFF	BODY	FRUIT	ORNAMENT	SPACE	BRICK	PIN	FREE	NARROW
ON	BRASS	GLASS	OWNER	STAGE	BRIDGE	PIPE	FREQUENT	OLD
OVER	BREAD	GOLD	PAGE	START	BRUSH	PLANE	FULL	OPPOSITE
THROUGH	BREATH	GOVERNMENT	PAIN	STATEMENT	BUCKET	PLATE	GENERAL	PUBLIC
TO	BROTHER	GRAIN	PAINT	STEAM	BULB	PLOUGH	GOOD	ROUGH
UNDER	BUILDING	GRASS	PAPER	STEEL	BUTTON	POCKET	GREAT	SAD
UP	BURN	GRIP	PART	STEP	CAKE	POT	GREY	SAFE
WITH	BURST	GROUP	PASTE	STITCH	CAMERA	POTATO	HANGING	SECRET
AS	BUSINESS	GROWTH	PAYMENT	STONE	CARD	PRISON	HAPPY	SHORT
FOR	BUTTER	GUIDE	PEACE	STOP	CART	PUMP	HARD	SHUT
OF	CANVAS	HARBOUR	PERSON	STORY	CARRIAGE	RAIL	HEALTHY	SIMPLE
TILL	CARE	HARMONY	PLACE	STRETCH	CAT	RAT	HIGH	SLOW
THAN	CAUSE	HATE	PLANT	STRUCTURE	CHAIN	RECEIPT	HOLLOW	SMALL
A	CHALK	HEARING	PLAY	SUBSTANCE	CHEESE	RING	IMPORTANT	SOFT
THE	CHANCE	HEAT	PLEASURE	SUGAR	CHEST	ROD	KIND	SOLID
ALL	CHANGE	HELP	POINT	SUGGESTION	CHIN	ROOF	LIKE	SPECIAL
ANY	CLOTH	HISTORY	POISON	SUMMER	CHURCH	ROOT	LIVING	STRANGE
EVERY	COAL	HOLE	POLISH	SUPPORT	CIRCLE	SAIL	LONG	THIN
NO	COLOUR	HOPE	PORTER	SURPRISE	CLOCK	SCHOOL	MALE	WHITE
OTHER	COMFORT	HOUR	POSITION	SWIM	CLOUD	SCISSORS	MARRIED	WRONG
SOME	COMMITTEE	HUMOUR	POWDER	SYSTEM	COAT	SCREW	MATERIAL	
SUCH	COMPANY	ICE	POWER	TALK	COLLAR	SEED	MEDICAL	
THAT	COMPARISON	IDEA	PRICE	TASTE	COMB	SHEEP	MILITARY	
THIS	COMPETITION	IMPULSE	PRINT	TAX	CORD	SHELF	NATURAL	
I	CONDITION	INCREASE	PROCESS	TEACHING	COW	SHIP	NECESSARY	
HE	CONNECTION	INDUSTRY	PRODUCE	TENDENCY	CUP	SHIRT	NEW	
YOU	CONTROL	INK	PROFIT	TEST	CURTAIN	SHOE	NORMAL	
WHO	COOK	INSECT	PROPERTY	THEORY	CUSHION	SKIN	OPEN	
AND	COPPER	INSTRUMENT	PROSE	THING	DOG	SKIRT	PARALLEL	
BECAUSE	COPY	INSURANCE	PROTEST	THOUGHT	DOOR	SNAKE	PAST	
BUT	CORK	INTEREST	PULL	THUNDER	DRAIN	SOCK	PHYSICAL	
OR	COTTON	INVENTION	PUNISHMENT	TIME	DRAWER	SPADE	POLITICAL	
IF	COUGH	IRON	PURPOSE	TIN	DRESS	SPONGE	POOR	
THOUGH	COUNTRY	JELLY	PUSH	TOP	DROP	SPOON	POSSIBLE	
WHILE	COVER	JOIN	QUALITY	TOUCH	EAR	SPRING	PRESENT	
HOW	CRACK	JOURNEY	QUESTION	TRADE	EGG	SQUARE	PRIVATE	
WHEN	CREDIT	JUDGE	RAIN	TRANSPORT	ENGINE	STAMP	PROBABLE	
WHERE	CRIME	JUMP	RANGE	TRICK	EYE	STAR	QUICK	
WHY	CRUSH	KICK	RATE	TROUBLE	FACE	STATION	QUIET	
AGAIN	CRY	KISS	RAY	TURN	FARM	STEM	READY	
EVER	CURRENT	KNOWLEDGE	REACTION	TWIST	FEATHER	STICK	RED	
FAR	CURVE	LAND	READING	UNIT	FINGER	STOCKING	REGULAR	
FORWARD	DAMAGE	LANGUAGE	REASON	USE	FISH	STOMACH	RESPONSIBLE	
HERE	DANGER	LAUGH	RECORD	VALUE	FLAG	STORE	RIGHT	
NEAR	DAUGHTER	LAW	REGRET	VERSE	FLOOR	STREET	ROUND	
NOW	DAY	LEAD	RELATION	VESSEL	FLY	SUN	SAME	
OUT	DEATH	LEARNING	RELIGION	VIEW	FOOT	TABLE	SECOND	
STILL	DEBT	LEATHER	REPRESENTATIVE	VOICE	FORK	TAIL	SEPARATE	
THEN	DECISION	LETTER	REQUEST	WALK	FOWL	THREAD	SERIOUS	
THERE	DEGREE	LEVEL	RESPECT	WAR	FRAME	THROAT	SHARP	
TOGETHER	DESIGN	LIFT	REST	WASH	GARDEN	THUMB	SMOOTH	
WELL	DESIRE	LIGHT	REWARD	WASTE	GIRL	TICKET	STICKY	
ALMOST	DESTRUCTION	LIMIT	RHYTHM	WATER	GLOVE	TOE	STIFF	
ENOUGH	DETAIL	LINEN	RICE	WAVE	GOAT	TONGUE	STRAIGHT	
EVEN	DEVELOPMENT	LIQUID	RIVER	WAX	GUN	TOOTH	STRONG	
LITTLE	DIGESTION	LIST	ROAD	WAY	HAIR	TOWN	SUDDEN	
MUCH	DIRECTION	LOOK	ROLL	WEATHER	HAMMER	TRAIN	SWEET	
NOT	DISCOVERY	LOSS	ROOM	WEEK	HAND	TRAY	TALL	
ONLY	DISCUSSION	LOVE	RUB	WEIGHT	HAT	TREE	THICK	
QUITE	DISEASE	MACHINE	RULE	WIND	HEAD	TROUSERS	TIGHT	
SO	DISGUST	MAN	RUN	WINE	HEART	UMBRELLA	TIRED	
VERY	DISTANCE	MANAGER	SALT	WINTER	HOOK	WALL	TRUE	
TOMORROW	DISTRIBUTION	MARK	SAND	WOMAN	HORN	WATCH	VIOLENT	
YESTERDAY	DIVISION	MARKET	SCALE	WOOD	HORSE	WHEEL	WAITING	
NORTH	DOUBT	MASS	SCIENCE	WOOL	HOSPITAL	WHIP	WARM	
SOUTH	DRINK	MEAL	SEA	WORD	HOUSE	WHISTLE	WET	
EAST	DRIVING	MEASURE	SEAT	WORK	ISLAND	WINDOW	WIDE	
WEST	DUST	MEAT	SECRETARY	WOUND	JEWEL	WING	WISE	
PLEASE	EARTH	MEETING	SELECTION	WRITING	KETTLE	WIRE	YELLOW	
YES	EDGE	MEMORY	SELF	YEAR	KEY	WORM	YOUNG	

SUMMARY OF RULES

PLURALS IN 'S'

DERIVATIVES IN 'ER' 'ING' 'ED' FROM 300 NOUNS

ADVERBS IN 'LY' FROM QUALIFIERS

DEGREES WITH 'MORE' AND 'MOST'

QUESTIONS BY INVERSION AND 'DO'

OPERATORS AND PRONOUNS CONJUGATE IN FULL.

MEASUREMENT, NUMERALS, CURRENCY, CALENDAR, AND INTERNATIONAL TERMS IN ENGLISH FORM

THE ORTHOLOGICAL INSTITUTE
10
KING'S PARADE,
CAMBRIDGE,
ENGLAND

Scientific planning applied to spoken and written communications The total vocabulary of Basic English, which is capable of serving as a universal auxiliary language.

[*By courtesy of the Orthological Society.*

or Ido, a dead language like Latin, an existing language like French or English, or a simplified existing language like Basic English, with or without simplified spelling?

I said at the outset that in this chapter I was deliberately not going to tie myself down to the more straightforward method of treatment I have been using for other subjects. So I feel that in winding up this chapter I can allow myself a little more scope than usual in the way of speculative freedom.

Let us not forget that, far from progress being at an end, it is going on at a more rapid rate than ever. During the past two years, man has penetrated into two new regions of the planet—the stratosphere and the deep sea. With their new type of hermetically sealed balloon cars, Professor Piccard, and then the Americans and the Russians, have reached a layer of the atmosphere where conditions are altogether different from those near the surface of the earth—intense cold, low pressure, absence of cloud, different wind-systems, and so on. The Americans meanwhile, in their hermetically sealed diving-bells, have reached an equally unfamiliar zone of the sea, where there is complete darkness, complete calm, completely equable low temperature, where no green plants exist, and where theirs have been the first human eyes to see the fantastic deep-sea creatures in natural conditions.

Man can doubtless extend these explorations much further in both directions. Already the physicists and mathematicians are discussing the methods by which a rocket plane could be hurled at enormous speed through the tenuous resistance of the stratosphere. Romantically-minded popularizers of science have gone further, and toyed with the idea of interplanetary

communication, whether by signals on a vast scale, or by actual transport across the huge empty spaces. That is at the moment an unpractical and fantastic dream. But do not let us forget that for our descendants (our very remote descendants !) it is likely to be a pressing practical problem. Eventually this earth is destined to cool down until a point is reached at which life is no longer possible upon or even within its surface. The other planets of our solar system are destined to cool down in the same way. But as they are of very different sizes, they will cool down at very different rates, and the bigger ones will of necessity remain as places where human existence is at least physically possible long after the earth has become a frozen lump To be able to cross interplanetary voids then would in all likelihood mean the prolongation of the life of our species by many hundred million years. Admittedly the problem is hardly urgent—the astronomers give us the probability of a thousand million years' existence on our present planet. But it is worth remembering that that is the sort of Last Judgment which science pictures for humanity.

But interplanetary communication, staggering though it may be as an idea, represents only a quantitative extension of ordinary transport. You would still just be going from one place to another; the places merely happen to be farther apart. So let me end with another speculation, about a development which would involve a new *kind* of communication: I mean the development of telepathy. By telepathy is meant the direct communication of thought or feelings between people without the aid of any of the ordinary channels of expression—words, writing, gesture, facial expression,

and so on. You will find many people firmly believing in it and many others equally firmly disbelieving. On the evidence, there seems certainly a strong *prima facie* case for its existence; but it has so far been impossible to bring it within the field of science at all By this I mean that though things happen which seem explicable only on the assumption of telepathy being a fact, no one has yet found any way of getting telepathic communication repeated at will, or under any sort of proper control; so that scientific study of *how* the process happens has been impossible.

But if we once grant that it can happen, we must believe that our descendants will one day be able to understand, and then to control, its workings. And then the most extraordinary possibilities open out Would we be able to open and shut our minds to each other at will? Or if, for instance, it were possible to get thousands of people all to feel a similar emotion in telepathic unison, would the emotion itself in each individual be intensified? The possibilities are endless. But they could never be realized unless one first step can be taken—the first step of giving a scientific description of telepathy, instead of just having the probability that it exists Orthodox science at the moment tends to fight shy of such so-called supernormal psychology. But this field, as yet scientifically untilled, might be intensely fruitful. Perhaps in a hundred years' time there will be a Telepathy Research Station as well as a Radio Research Station. Meanwhile the problem is how to make a new field amenable to scientific research; and—something new in this survey of mine—how to make science itself more scientific in its approach to this unexplored region of phenomena.

CHAPTER VIII

RESEARCH AND INDUSTRY

Discussion with Sir Thomas Barlow

J H Well, Barlow, I am glad to have you here for this discussion. You see, I am a very academic scientist, and my special knowledge is all in a branch of science remote from application in most of industry. So that as I go round visiting works and research associations and universities, and trying to appraise the meaning and value of science in satisfying social needs, I sometimes wonder what sort of practical value there really is in the conclusions I have been reaching. And accordingly I am very glad to have someone like yourself—someone who is actually engaged in producing and selling things—to give an opinion about the relation between science and industry, because the public is naturally interested in opinions from the industry end as well as opinions from the science end

T. B. And I am glad to be here, Huxley. It is an important subject. I think I had better set the ball rolling by asking you what general views you have come to so far on the relation of science to industry.

J. H. Well, first of all, everything I have seen has strengthened the opinion I held before—that science and research are absolutely necessary for industry in this country—necessary not only for its improvement, but also for its survival.

T. B. How do you mean?

J. H. I mean that conditions are changing so fast all over the world that you must have research just to keep up with them; quite apart from keeping up with all the research that is going on in other countries.

T. B. Yes, that is true enough. New means of communication are coming into existence, new supplies of raw materials are being discovered, new markets are being opened up, new political, economic, and cultural developments are taking place. Of course, industry must adapt itself to these new conditions. I take it you mean that it cannot afford to adapt itself slowly, hit-or-miss;—it must use the scientific method.

J. H. Exactly. After all, just as, in the evolution of animal life, the power of thinking develops as a substitute for the wasteful method of action by trial and error, so, in the development of civilization, scientific research comes in as a substitute for the slow, unconscious methods of rule-of-thumb tradition Science in the long run saves so much time and money and energy that without it you just get left behind in the race.

T. B. Yes, I think most people would agree with you there But that is all very general. I want you to tell me about the particular ways in which you think science can help industry.

J. H. Well, the first thing that has struck me is the immense value of scientific method for standardization. I have said a good deal about this in earlier chapters, so I will not add much here. But it is pretty clear that an industry cannot be fully efficient unless it has standard specifications for its raw materials, standard processes, and standard products. You want standard

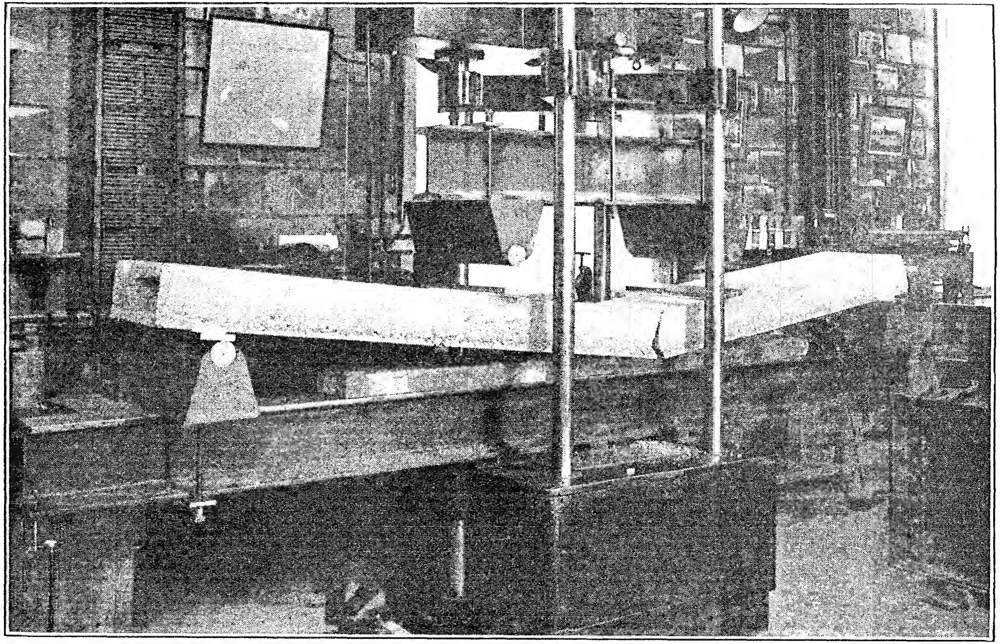
raw materials, because otherwise you are at sea in your processes. A builder must know the strength and other qualities of the steel girders, and of the lime and bricks he must use. Does it not come in in your field too?

T. B. Yes, of course—to take only one example, the more precise knowledge a cotton spinner has of his raw material, the better his yarn.

J. H Standard materials, yes. Then you obviously want standard processes, because otherwise you will get undesirable variations in the product, and waste in the process. A tanner wants to know the exact acidity at which the tanning process goes best, as well as to be provided with standard tanning materials. The cement manufacturer wants to know the precise temperature and the exact proportions of silica, alumina, and lime which give the best results with the least expenditure; and the buyer of his product, of course, wants to be sure it is of standard quality. All this cannot be ensured unless you make a painstaking, and often very difficult, scientific study of the raw materials and the industrial processes involved. It is rather dull, unspectacular work on the whole, but seems to me to be absolutely necessary if an industry is to have the flexible scientific basis which modern conditions demand, instead of the slower, more rigid, less conscious traditional basis of earlier times.

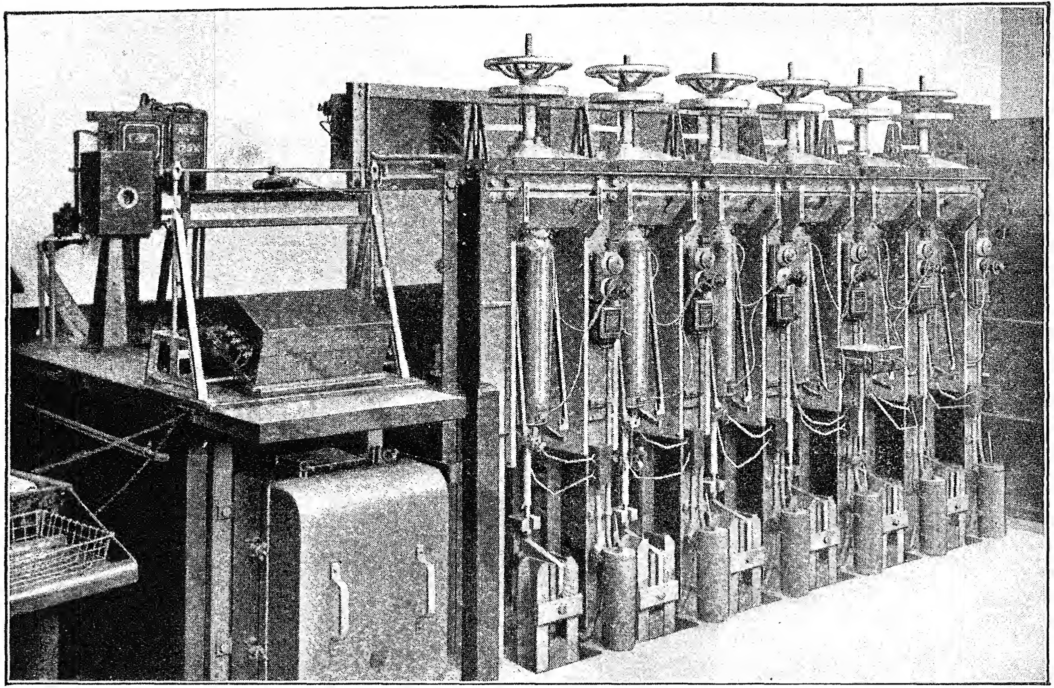
And then besides standard materials and processes, I take it you want standard products too.

T. B. Well, in my opinion undue change and an undue variety of products impede production more than almost anything else. I am sure that there are at the present time a great many commodities in which the existing variety could be reduced with advantage.



Testing for standard strength in materials: a concrete floor-beam being compressed transversely until it breaks, at the Building Research Station, Watford. (*See* pp. 55, 128.)

By permission of the Controller of H.M. Stationery Office.



Testing " creep " in steel. A group of six creep-testing units which can measure infinitesimal movements of steel specimens subjected to tensile strain up to several tons per square inch and at constant temperatures up to 1600° F. The rate of extension of the steel can be as low as one-hundred-millionth of the original length per hour (less than one ten-thousandth per year) and yet be detected by these machines. (*See* p. 132.)

By courtesy of Metropolitan-Vickers Electrical Co., Limited.

Look at man's clothing, for an example. Does the average man worry very much about his clothes, provided they are reasonably serviceable and fit him properly? Would not the majority of mankind have all it really needs if it were given a quite limited range of colours, styles, and qualities? Don't you remember during the War being struck by the extraordinary improvement in many young men's appearance when they changed their civilian attire for an officer's tunic and breeches? Yet those garments were essentially simple in outline and not attractive in colour. I mention that as an instance of how uniformity of clothing does not necessarily create an impression of dull mediocrity.

The same considerations surely apply to lots of things in everyday household use—electric-light switches, dusters, telephone receivers, bed-sheets—these are one or two which come to my mind as I am speaking. And in the same way why cannot different nations have the same stamps, the same coinage, the same weights and measures, the same rule of the road? Variety in all these only adds to the confusion of life.

J. H. But, my dear Barlow, you are heading straight for a Robot world! Is not variety the salt of life?

T. B. Your protest, Huxley, leaves me cold. And, in any case, you did not let me finish. Of course I do not want standardization in everything. It is to be avoided wherever emotional or spiritual or æsthetic values predominate. Rooms would be very dull if there were only a dozen patterns of furnishing fabrics to choose from—and as for women's wear, it would be a very grim business if there were only, say, six patterns of printed dress materials available. And as for their

underclothes, I don't think they should be made only from plain white calico. However, we need not worry about that—the ladies will see to it.

But what I really wanted to say was this. Standardization in many commodities is a liberating force, and does not impoverish life æsthetically. In other commodities it does, and there we must avoid it.

J. H. I think I agree—with the proviso that even with products where variety is desirable, you may need standardization of raw materials and processes; the variety emerges in the manufacture.

T. B. Agreed. Well, after standardization, what next?

J. H. Improvement. It is obvious that once you have understood the scientific basis of a process—say making glass, or tempering steel, or scouring wool, you can begin to improve it scientifically. This type of research, too, is generally a slow and tedious sort of job. But it brings sure returns in securing greater efficiency, bigger output, and better products. Think, for instance, of the aeroplanes, the radio valves, the artificial silk fabrics of to-day, and compare them with those which could be produced in the early days of the industries concerned. The difference is enormous—and the improvement has been due in the main to the steady application of science to the problem. Just the same would be true if you looked at processes instead of products; only one needs more special knowledge to appreciate the progress there has been. I take it you will agree on this too?

T. B. Yes, except that I should have imagined that the results would have been even more spectacular sometimes.

J. H. That is true There is the classical example of the electric-light bulb. There has been a perfectly steady improvement from the original lamps of Swan and Edison, with their splinters of bamboo glowing in a vacuum, to the lamps of to-day These had an efficiency (measured in terms of the proportion of the energy going into them which comes out as light) of well below 0·5 per cent. The best gas-filled bulbs of to-day have an efficiency of about 2 per cent. Some hot cathode lamps in commercial use give one of 10 per cent., and some still in the experimental stage one of about 50 per cent In length of life the improvement has been still greater.

Even since the introduction of our modern gas-filled tungsten filament bulbs the improvement has been so great that it would not pay you to take as a gift a lamp which was the latest pattern five years ago in place of buying a 1934 type—because its efficiency was less and its life much shorter. This pronouncement was made to me by the head of the research laboratories of an important firm in the electrical industry.

Then what is going on in the metal-testing department of the National Physical Laboratory and a number of other places is spectacular enough. For instance, they are doing some most interesting work on what is called *creep* in a metal such as steel—very, very slow distortion under whatever forces are acting on the metal. With lead, which is soft, creep may be obvious: the lead in lead roofs may actually move downwards, causing the roof to thin out near the top and be thickened and thrown into waves near the bottom. But even the hardest steel is subject to some degree of creep. It is important, naturally, to keep this down

to a minimum in fine machinery, and so you have the testing of different steels for low creep—you put a heavy load on the piece of steel at whatever temperature is needed, and then, by means of a special device, measure its infinitesimal movements. Until quite recently the highest standard was that a bit of metal of a given length should not show a movement of more than one millionth of its length per day. Recently, however, new machines, such as high-speed turbines, put such demands on their materials that the manufacturers themselves have demanded a test a hundred times more strict—one part in a hundred million per day—which means a permissible change of well under a twenty-thousandth part of an inch during a year in a piece of steel a foot long. Think of what that means in terms of skill in making steel !

T. B. Yes, that is spectacular enough !

J. H. But I want to ask your opinion about another kind of improvement—invention. I have the impression that we do not do nearly enough to mobilize inventive genius. And by inventive genius I mean something rather different from scientific genius. The inventor is someone who has (or thinks he has) a flash of insight about improving a machine or a process. He may be all wrong about the scientific basis of his idea, and extremely vague about the practical means of applying it. But the idea may be very valuable. As things stand in this country, the inventor often gets lost in the mazes of the patent law, or, if he manages to get a business man to take any interest at all in him, finds himself forced to sell his invention at a ridiculously low figure.

T.B. Well, Huxley, I can only say that my experience

has been that the business man is much more likely to lose money on a new invention than to make it, though I admit there are exceptions.

J. H. But that emphasizes just what I wanted to bring out—the need for *organizing* invention and incorporating it into the framework of industry In Soviet Russia they have a very interesting system for encouraging inventors, and, if their ideas are any good, of giving them a thorough scientific training and a better position The only attempt I have seen in this country to link up invention with industry—as science has already been linked up—was in a firm which made machines for making boots and shoes—wonderful machines a lot of them are, too Here they had a set of rooms occupied by a staff of six or eight men officially styled Inventors, under a senior Inventor, who were busy all the time with ideas improving the machines In another office was a staff of Designers, who were responsible for the job of realizing the inventors' ideas in the practical designs.

T. B. I see—you mean the inventor is rather a special type, and you want to use him to the best advantage?

J. H. Exactly. But we must get back to research in general Next comes something much more spectacular—research which leads to new *processes* Sometimes it may lead simply to the substitution of a new process for an old, with an increase in efficiency, but without any particular effect on the product In an earlier chapter I gave an example from the leather industry—the substitution of the clean and accurate trypsin process for the dirty and untidy use of animals' dung. Or the new process may be so much of an improvement that it transforms the industry.

T. B. Yes, like chemical bleaching in the industry to which I belong. You mentioned this in one of your previous chapters, and pointed out that without chemical bleaching it would have been impossible to produce cotton goods on a large scale and at a low price.

J. H. Yes, I think that is as good an example as one could find. Or again, the new process may lead to the introduction of a new *kind* of product. I saw an example of this in the big Brown-Firth steel works at Sheffield, where research led to the production of rustless and stainless steel. Or there is vita-glass—or high-speed tools with the properties of best steel, but with no iron in the alloys of which they are made—or the application of low-pressure gas tubes to street lighting.

Or the product may be so new as to become the basis of a new branch of industry altogether. The classical example is Faraday busy in the laboratories of the Royal Institution with funny-looking coils of wire—and laying the foundations of the whole of electrical industry. A more modern instance is Fleming's discovery of the new principle now used in all wireless valves.

Improvement of this type may be sporadic—the result of the research of a gifted individual in a University laboratory, for instance. Or it may be systematic: let me give examples of what I mean by this. We exist under a pressure of fifteen pounds to the square inch, and are used to the way things happen at that pressure. But at higher pressures many things happen quite differently. For instance, at a pressure of a few hundred atmospheres, all sorts of reactions involving

gases will take place which otherwise will not occur except at huge temperatures. It was research of this sort which led the great German scientist Haber to perfect his method for using the nitrogen of the air to make ammonia, and with the ammonia to make fertilizers and all sorts of other important substances. I suppose this work did more to prolong Germany's powers of resistance to our blockade than that of any other single man.

The other day I was visiting the wonderful research laboratory at the Alkali branch of Imperial Chemical Industries, at Northwich, and there they told me that Haber gave a lecture in England in 1911 on some of the theoretical aspects of this work. If at the time they had been engaged on systematic research on gas reactions at a few hundred atmospheres, in all probability, they said, they would have realized the practical possibilities inherent in his talk, and we too should have had the ammonia process of fixing nitrogen during the War. As it was, British science had not the necessary background, and Britain had to wait ten years for cheap nitrogen.

They are determined not to be caught out again, so they are now systematically surveying what happens—not at a few hundred atmospheres, for that field is now pretty well explored—but at a few thousand atmospheres—round fifty thousand pounds to the square inch, which is the sort of pressure you get inside a big naval gun at the moment of the explosion!

At this sort of pressure, many liquid reactions involving organic compounds go on altogether differently from what they do in ordinary terrestrial conditions. In addition to the great scientific interest of

the work, they expect to obtain important practical results themselves, as well as gaining the background which will enable them to appreciate the implications of similar work published by others.

Eventually they may start working with tens of thousands of atmospheres—under which conditions the most extraordinary things may happen: phosphorus, for instance, goes black and changes its properties so that it behaves like a metal!

The electrical experiments with enormous voltages which I saw at Metro-Vickers and at the National Physical Laboratory are rather similar. Apart from lightning, such electrical conditions do not exist on this planet. To study them means studying a little artificial world that science has created. Or take one more example—the behaviour of substances at intensely low temperatures, only a few degrees above absolute zero. Man has now brought the temperature of interplanetary space into his laboratories; and he finds that at these temperatures, electrical properties change profoundly—electrical resistance, for instance, practically disappears; so that a current will go on for years and years flowing round and round a closed circuit without appreciable loss

T. B. That point about the need for the right background is specially interesting to me. I think it applies to owners and directors as much as to research workers.

J.H. I am glad to hear you say that. I want to bring it up later. But meanwhile let me finish my catalogue of the results of research. I have only got one more item, and that is research to discover new *uses* of materials and products. For instance, when I visited

the Glass Technology Department of Sheffield University, I heard a good deal about the new uses of glass. Glass is chemically very resistant: it can be made opaque, or slightly translucent so as to let through a faint light of any colour you like: it can be made in blocks of any desired shape or size. All these properties are valuable for building And, as a matter of fact, glass has been used for building houses for some time: there are several glass houses on view at the World's Fair in Chicago. Then it can be made black, in sheets, as a surface lining. It has been used thus on the outside of the new *Daily Express* building in Fleet Street, and, in combination with stainless steel, to line the inside of the new road tunnel under the Mersey, so as to prevent dazzle.

T. B. That sounds attractive

J. H. Yes—I should like to see it. Then, too, a great deal of research is going on in various laboratories on new uses for coal. Every one has heard of the processes for getting petrol out of coal, whether by low-temperature carbonization or by the higher-yielding method of hydrogenation, which is now about to be put into commercial practice on a large scale by I.C.I. But other important work is going on, designed to produce really satisfactory smokeless fuels for domestic purposes, from coal and from coke. (In regard to coke, the chief trouble in the past has been the variation in the standard and quality of the product) This smokeless fuel work, of course, is of value not only to the producers and users of the fuel, but to the nation as a whole—in reducing the ridiculous waste—waste of valuable substances discharged into the air, waste of paint and stone and metal corroded by fumes, waste of

physical and mental health engendered by the foul and unnecessary smoke-palls over all our great cities.

While we are on the subject of new uses, perhaps you can tell me something about research into new uses for cotton?

T. B. Well, I believe you mentioned in an earlier chapter the huge use of cotton in motor tyres, and its growing employment for insulating material. In addition, I believe there is immense scope for new fabrics, especially those consisting of mixtures of cotton with other materials. I think that can be classified as a *new use.*

J. H. Yes, I think it can. Well, that is a list of the divers ways in which science can be applied in industry—standardizing materials and processes, improving processes, introducing new processes and products, and finding new uses for materials.

T. B. That is an impressive list all right. But look here, Huxley, is the work being *organized* in the right way, in your opinion?

J. H. Yes, that problem of organization is important. It also involves asking where all the funds for research come from. That sounds a bit dull, but I don't think it is really.

T. B. Well, where the money comes from does not sound a dull subject to me! Go ahead! let us hear what you have got to say about the organization of research.

J. H. All right. I have been finding out something about it during these last few weeks. In the first place, you may have research carried out, and of course paid for, by private firms, big or little. Then there is the work that goes on in the Research Associations

under the Department of Scientific and Industrial Research (let me save trouble by giving it its usual abbreviation—D.S.I.R). These are each controlled by a particular branch of industry. Some of the money for them comes from Government sources, the rest from subscriptions from the firms who are members (by no means all of the firms in the industry belong). I have been to see a good many of these institutions—for instance, those dealing with wool, cotton, leather, and laundering; but there are plenty of others—about twenty in all

Then there are the special Research Stations, also under the D S I R., which deal with problems where the interests of the consumer or the nation at large are so important that the Government wants to keep a good deal of control. So most of the money for them comes from Government sources They deal with problems like building, about which I said a good deal in an earlier chapter, cold storage, radio, forest products, and fuel research.

There is also that wonderful place the National Physical Laboratory, which in many of its activities acts as a central research institution for industrial problems too large-scale or too long-range to be carried on elsewhere. This also is under the D.S I R.

And then, of course, there is all the work carried on at Universities. Many people either forget or do not know how much of the work done at these so-called academic institutions is closely linked up with industrial needs. Leaving out of account what I may call the "background research" in very pure science, the applications of which cannot yet be seen (though we can be sure from the history of science that one day

they will be of immense importance), there exist departments in which very practical research is going on: civil, chemical, and electrical engineering, metallurgy, mining, oil technology, leather research, textiles, dyeing, fuel research, brewing, and so on. As one would expect, there are proportionately more of these in the newer universities of industrial towns like Sheffield or Leeds or Manchester than in London, Oxford, or Cambridge; but this type of semi-practical department is growing in the older universities as well. Some of the money comes from special endowments, old and new, and a good deal out of the Government Grant to Universities.

T. B. Well, did you reach any conclusions as to the part to be played by these different types of research organizations? For instance, when a firm is a member of a Research Association, is there any value in its carrying on with research on its own?

J. H. Oh, yes. By no means all of them undertake work on their own—but those that do seem to find it pay. There are special objectives which one firm may have—like the so-called creaseless cotton I spoke of earlier—which it could not entrust to a central organization if it wanted to keep the advantages to itself. This is the obvious sort of reason for doing your own research. Other examples are the new pattern wireless valves and the new kinds of lighting I saw at the General Electric Company, and the new, almost noiseless, electric motors for fans and so on that they are working out at Metro-Vickers.

But there is another and equally important reason for a private firm doing research—I touched on it in connection with the high-pressure work going on at I.C.I. It is to have on the spot a background of

research knowledge and the research spirit which will enable the firm to understand the value of the research done elsewhere, and so be able to apply it at once and in the right way. This is not of value only for large firms I came across one quite small firm, devoted almost exclusively to making small electric switch-gear, the director of which told me that not only was research essential for him if he was to achieve real improvement of his products, but also for keeping cost down—for instance, he had research in progress on the raw materials he bought, so as to be able to tighten up standards and specifications.

Those, I think, are the main functions of research by single firms. The main aim of work undertaken by Research Associations is rather the standardization and improvement of processes and products common to the industry as a whole or to large sections of it—the slow but vital work I spoke of earlier. Single firms, save for a few very big ones, cannot be expected to tackle this type of long-range work.

T. B. Well, how do the Universities come in? Are not their departments of applied science engaged in the same sort of long-range work?

J. H. No, not altogether. Naturally there is an overlap; but, on the whole, as you would expect, they are working on the problems rather more remote from application—the more basic questions. Often they do so to such good purpose that they convert a field which you would think was applied science into a pure science in its own right. Metallurgy is a good example of this. Don't forget, too, that half the job of these University Departments is training—training men to go out into industry imbued with

the scientific spirit as well as equipped with scientific knowledge.

T.B. That brings up a point I made earlier—one that worries me a good deal—the scientific training of owners and directors in industry. It is not a question of technical training so much as proper background.

J. H. Is not the trouble with many business people that they do not really grasp what the scientific spirit means?

T. B. I am afraid, Huxley, you are right. It is not merely a question of getting more trained scientists on our staffs. We ourselves, the directors and the proprietors, whatever we may be, do require training just as much as anybody else. We do not want to do the job ourselves, but we want to know what it means—what, so to speak, the language is, and what our fellows are talking about. Science, research, the scientific spirit, does not merely mean that you have a department where a number of persons sit over microscopes and pour liquids from one test-tube to another, but a fundamental attitude of mind; and I will admit quite frankly that we, or shall I say many of us, have been very remiss in this respect.

J. H. Is not that the reason for the rather lamentable fact that a number of Industrial Research Associations, in spite of substantial grants from Government funds, have become rather feeble or even defunct—the Cutlery Research Association at Sheffield is an example?

T. B. I suppose so; though, of course, bad times have contributed to it. In bad times, people will either give up the expense of research altogether, or concentrate on it rather desperately as a possible way out.

J. H. Well, the expense is not so very large, you know.

As far as I can make out, the cost of research associations comes to less than a shilling per £100 of net output—less than 0·05 per cent.

T. B. H'm—that certainly is not much.

J. H. No—especially when you contrast it with the amounts spent on advertisement. But would you think it reasonable that the Government should insist on more science, as a *quid pro quo* for what it does for industry, in the way of all the money it spends itself on scientific research, or as a premium on the efficiency which it surely has a right to demand if it gives an industry a protective tariff? You might have a levy on sales, or you might take a percentage of tariff receipts to make your central research fund.

T. B. These are rather thorny questions, aren't they? though well worth thinking over. But there is another even more general point that I do very much want to discuss. So far we have been assuming that science has been useful to industry in the past, and could be equally useful in the future. But, you know, there are some people who would like to lock up you and your fellow scientists, or at least keep you from doing any scientific work for ten years, or even for the term of your natural lives, because they feel that science is multiplying human needs so fast that it is making it harder for people to live a life that is really worth living.

J. H. That is going a bit far, isn't it?—though I do feel that eventually we shall have to try to adjust the tempo of research to the tempo of social development. But do *you* feel like that, Barlow?

T. B. No, I do not. All the same, I do feel like repeating this question: Is not science doing us a

disservice by unduly multiplying our wants? The moralists would have us believe that a man's happiness consists in the fewness of his wants—and we only increase the complications of life when we multiply the number of material commodities in the world.

J. H. That is true from one angle On the other hand, you do find to-day one school of social philosophers who preach that consumption is the great moral duty, don't you? It is a far cry from the views of Samuel Smiles and the *waste not, want not,* school of thought, and does help to prove that morality is relative to economic and social facts.

T. B. Moral duty! but this is not a discussion on morality, my dear Huxley.

J. H. I know; but you started it, Barlow.

T. B. All right, but leaving morals out, it is futile to try to turn our backs on science and say, "No more of this." Some people seem to think it possible for life and thought to stop at a given point—thus far and no further—but when life and thought stop, all we have is decay and death. Do we really want to smash up all our machines and go back to a new Middle Ages? Surely life can be just as much enriched by variety as it can be complicated and confused?

J. H. Very true. But we still remain in a great mess owing to our so-called over-production.

T. B. Yes. But have we called *all* the resources of science to our aid? What have we done in the way of using science to study consumption and distribution, as we have done for production?

J. H. Next to nothing, as far as I know. But give me some examples of what you mean.

T. B. Well, why is it that there is such a great increase

in the price of an article between the time when it leaves the factory and when it gets on to the counter of a shop?—a difference amounting often to over a hundred per cent.?

J. H. That, I suppose, is due partly to the high overheads. But is it not also due partly to the chaos that exists in retail distribution? I read recently that there were about six hundred thousand shops in this country—one to every seventy inhabitants—with no system of regulation, no attempt to see if the owner knows anything about what is really rather a difficult job to do well. Or look at the business of distributing milk. In some streets there are three separate firms who send their vans every morning. Would it not reduce costs if you could get one firm supplying one area entirely, instead of having to dodge in and out like this?

T. B. Doubtless that is true. But the main thing, I feel, is that we do not really *know* enough; that we just have not got the facts on which we could make a decision as to a course of action—at least a scientific decision. In this field we are without even the basis for science.

J. H. I am interested to hear you say that. For some time it has seemed to me that the first step towards getting a scientific outlook in economic and social matters is the proper collection and organization of facts. You could not have had modern biology until after the early naturalists had collected specimens of animals and plants from all over the world and arranged them in museums. In sociology, facts are the specimens, and proper statistics take the place of museum arrangement. Ought we not to have a really comprehensive statistical department, under Government

control, to collect the facts we need and arrange them in logical and convenient ways?

T. B. I quite agree with you, Huxley; and I would add that a great many of us manufacturers are much too suspicious about letting out statistics. The Americans are streets ahead of us in this respect.

J. H. Absolutely. Well, if there were a really adequate statistical authority in existence, then you would begin to get people linking up the facts about trade with the facts about population, the facts about public health with the facts about wages, and so on; and when assured knowledge comes in at the door, partisan spirit flies out at the window. You do not find people getting all worked up and holding elections to decide whether the chemical composition of water is H_2O or something quite different. A good dose of hard facts is the best remedy for party passions and hasty actions.

T. B. I must just put in an example on a small scale, from trade. I have heard of an enterprising firm of tailors that study the census returns very thoroughly, district by district, to find out just what sort of demand there is likely to be for gents' suitings adapted to men of different ages and social classes—with excellent commercial results.

J. H. Yes. That is an example of what one can do with the very limited statistics at present at our disposal. But just think of all the things you could study scientifically and arrive at undisputed conclusions about, if you had all the relevant facts to play with—all the things you cannot study now. Just as you cannot discover a new scientific law without you or someone else having first amassed a great deal of

scientific fact by means of patient study and measurement.

T. B. Yes. To take just one example, I have often wondered about advertisement. Obviously much advertising is useful and necessary, for the public as well as the advertiser; but equally obviously, one would think, there is some advertising going on which is useless or wasteful—or even harmful.

J. H. Quite. And there is no means at present of finding out where the line should be drawn.

T. B. But I suppose one could find out?

J. H. Yes, undoubtedly, if we could get the facts and have them properly analysed—as we could if we would take a bit of trouble. That is another of the subjects on which industry could get really reliable information if we had the machinery for studying it in a scientific way.

T. B. But our time is running out, Huxley, and we have not mentioned what I suppose is the most difficult problem of distribution and consumption, the greatest issue of all in relation to industry—I mean, of course, unemployment.

J. H. Unemployment—yes, I agree. If one can just manage to detach oneself from the misery and waste of it all, one cannot help reflecting on the irony of the situation. Here we have been talking about the wonders of the labour-saving machinery for the last century; and now that it really *is* saving labour, we are taken unprepared For, after all, the aim of labour-saving machinery should be to save labour, should it not? Yet you find people seriously worried at the prospect of machinery being able to do the hard work of the world with human labour reduced on the average to only a few hours a day.

However, it is difficult to see where science can come in, so long as the direction of affairs is in the control of politicians—no, I should really say in the control of blind economic and social forces that play with the politicians as much as they do with the common man

T. B But could not applied science feed and clothe and shelter not merely our present population, but double that amount?

J. H I daresay. But why, my dear Barlow, are you so anxious to see more people in the world? Quality of life, not just quantity, is surely the proper aim. But I do think that in bringing up this question, you have reminded me of something where science could help us in the present crisis. We could use science and the scientific method to study the problem of population, with a view to its ultimate control. You see what important issues are at stake. Yet in regard to birth-control, which is, after all, the most potent factor in any possible control of population, almost all the research that is going on in this country is under a small private committee which manages to raise a few hundred pounds a year by voluntary subscriptions!

T. B. Yes, it is obvious that there is a lot of scientific research and hard thinking to be done in this field. But one thing seems certain—whatever happens, the average man and woman, thanks to applied science, are going to have a great deal more leisure on their hands.

J. H. Yes. That is what I meant about labour-saving devices really saving labour.

T. B. But what are people going to do with all their leisure?

J. H. Ah, now you are asking! But, in any case, we

shall need a great deal of careful planning and organization to provide exciting, interesting, and satisfying outlets for people in their leisure time.

T. B. That blessed word *planning*! I am a little shy of it. Do you really think you can plan everything; or that, if you can, life will be worth living?

J. H. Now you are raising a question which would need another half-hour's discussion before we even began to see an answer! I entirely agree that there can be bad planning as well as good planning, and that bad planning obviously would have disastrous results; but, in the most general terms, is not planning an attempt to apply the scientific method all round, as we have already applied it to a fair extent in industry, and is not the alternative to planning, in the present state of civilization, merely chaos?

T. B. I suppose it is—but do not let us have any illusions about planning being a panacea. Some people seem to think that something valuable will result if they just say the word *planning* often enough—just as they did with the word *rationalization* ten years ago.

J. H. No, I have no illusions on that point. But I have real faith in science, and believe that in the long run human reason, employing the scientific method, will enable us to control our destiny.

CHAPTER IX

SCIENCE AND WAR

THIS chapter was not an easy one to plan out. One could approach the subject from so many angles. Perhaps I had better begin by giving a sort of table of contents, so that my readers can pick up the steps in my argument more easily.

To begin with, I cannot describe much war research, because most of it is kept secret. What one does know, however, is the amount of money spent by the Government on it; this is very large.

Then I shall argue that so long as there is a risk of war we must use science in our preparations for it, to get greater efficiency; but that we should also try to use science to reduce the risk of war.

In passing, I shall show how we cannot use science for war purposes without getting some set-off in the shape of useful peace-time improvements, and shall illustrate this by examples, especially from research on aviation. All the same, we could get the useful results much more easily by research aimed directly at them.

I shall say something on the need for cutting down wasteful expenditure in war research, and then go on to the point about using science to help disarmament. This can be done in part by making a detailed technical study of armament, which reveals the fact that there

will always be several months' lag in reaching the mass-production of armament material needed for modern warfare—whether you start from scratch, or have to convert a factory from peace-time uses This leads to the conclusion that to minimize the risk of war, the large-scale manufacture of war material should, as far as possible, be prohibited in peace-time, for this will give a time-lag before full-scale hostilities can begin, during which arbitration may get busy. In this connection I shall also discuss the attitude of scientists to the use of science for war preparations.

Science could also undoubtedly help in research upon the actual causes of war, psychological, economic, and political; but the astonishing fact emerges that no organized research at all has been done on these problems.

Meanwhile, it seems clear that so long as the world is organized into national sovereign states, the risk of war will continue to be very high; so here again science is up against political facts, and can only suggest that the most important step to reduce the immediate risk of war is some surrender of sovereign rights by nations to a supernational authority.

That, roughly, is the outline of what I am going to say. I am sure I shall be criticized, from both sides; but the dispassionate setting down of facts, so far as they are available, cannot well do harm, and that is what I shall try to do.

You will note I say "so far as available." That is because, as everyone knows, a great many of them are *not* available. Secrecy is the all-but-universal accompaniment of war research.

One thing available, however, is the expenditure

on research, which any one can dig out of Government documents: and we may perhaps begin with that.

For comparison we may take the amounts spent on some other kinds of research. For instance, on research connected directly or indirectly with industry in the year 1931–32 the Government spent, through the D.S.I.R., a little over half a million pounds; and on medical research, through the Medical Research Council, £139,000.

When we come to the Services, matters are more difficult to interpret, for in the parliamentary estimates of service expenditure, you will sometimes find included under research all sorts of expenses incurred for technical development which would not be classed as research by a private firm, and would not be undertaken at all by bodies like the D.S.I.R. or the M.R.C.

To take one example, the total budgeted for Research and Technical Development in this year's Air Estimates is over one and a third million pounds. But only about one-third of a million pounds goes to what can really be called research. Development is purely technical, not what is usually called "development research," and is a different branch, under a separate head. Even so, one-third of a million pounds for air research—more than twice as much as what is spent by the Government on medical and health research—is a lot of money, and a hundred thousand pounds for gas research is another heavy item. There can be no doubt that the total spent by the Service Departments on what can legitimately be called scientific research is well over a million a year. This would be of the same order of magnitude, though I think actually not quite as much,

as the Government expenditure in all other kinds of research lumped together.

This is a bit of a shock. But you must not forget several important facts. First, whereas there is relatively little research for war purposes that is not financed by the Government (the only exceptions are the makers of rather special armaments, like tanks or aero engines or armour-plate), there is a great deal for peace purposes In industrial research, for instance, private firms subscribe rather more each year to the Research Associations than comes from Government sources, and the amount spent by private firms on their own research is probably not less than two million pounds

Similarly, in medicine there is all the work done by the hospitals; and in pure science, all that done by the Universities and special research institutions, out of the proceeds of fees or, more usually, special endowments; all the work made possible by Rockefeller and other special fellowships; and so on.

This makes a difference, and so does the fact that the half-scale and full-scale work—development research—must inevitably be larger in proportionate amount in war than in industry, for instance. Take airships as an extreme example—think of the amount which large-scale research must have cost in proportion to the actual costs of construction—in a sense, the construction *was* research. But the same sort of thing happens in regard to new types of tanks or aeroplanes, where an enormous amount of research must go on in respect of a total output which would seem relatively very small in industrial practice.

Yet even when all such allowances are made, the

amount spent on research for war purposes does loom very large—all this money being spent on preparing more efficient destruction, or on more efficient defence against destruction, which would not be needed if there were no risks of war

What are we to say about this aspect of scientific research? As far as I can see, there is only one truly realistic attitude to be adopted about the relation between science and war. I leave out of account the revolutionary attitude, such as that of Communism, which is directed towards overthrowing by force the present type of government, since, whatever its views might be at present on the ideal desirability of abolishing war, in the event of its success it would immediately be confronted with the same problem as now confronts existing governments, bourgeois or otherwise. We have seen this happen in Soviet Russia: a communist state, pledged to the ultimate ideal of world peace, has been forced by the logic of facts into very large military expenditure.

The realistic attitude as I see it is this—that so long as there is a real risk of war, the fullest resources of science should be used for two purposes: to make warfare as efficient as possible from the military point of view at the lowest possible cost, and also to make war as unlikely as it is possible to make it in a world of independent sovereign states.

I contrast this realistic view with two opposed unrealistic views—one that of the emotional pacifist who brands as immoral any scientific man who gives any help whatever in war matters; the other that of the emotional patriot who puts the increase of armaments before anything else, and would like science as a

whole to be dragooned in the interests of war. The former is unrealistic in not taking account of the real risk of war in present circumstances; the latter is unrealistic in not seeing that heavy armaments, as well as increasing the risk of war, constitute an impossible strain on the resources of a nation.

There are, of course, all possible variations on these main themes. Many people adopt half the realistic attitude—the half about using science to make war more efficient if it does come; but do not think about its other side—the possibility of using science and the scientific method to reduce the risk of war. This is as if a state-run fire insurance company were to employ all the resources of statistics and scientific management in calculating its premiums and dealing with its business routine, but to take no steps to enforce building regulations about safety from fire outbreak, or to reduce arson.

But I shall come back later to this aspect of science in relation to war. For the moment, let me concentrate on the first half of my thesis.

This, be it observed, is *not* the same thing as the old Latin adage that if you wish peace, you should prepare for war. It asserts something much less sweeping—and much less questionable—that if you prepare for war, you should prepare for it scientifically.

The reason is simple. If you do not, then in the event of another war, you will be overwhelmed. Let us first get quite clear about this. Between 1911 and 1925, the size of the biggest naval guns increased from 12-inch to 16-inch, with an increase of weight of projectile from 850 to 2,000 lbs., an increase of range from rather over 11 to nearly 20 miles, and a

greater accuracy at high ranges. Now, since in naval warfare, so long as big ships are used at all, victory (I quote the expressive words of the *Encyclopædia Britannica*) "will always rest with the side that can hit the hardest at the longest range," it is pretty obvious that to keep a navy and not to use all the resources of pure and applied science to increase the size and range of your guns, is pure waste of life and money.

Or take another example. The most spectacular single change in war methods which arose during the Great War, apart from the introduction of aeroplanes, was the use of gas It does not seem probable, from what we know of organic chemistry, that any radically new gases capable of military use, more deadly than those already discovered by the end of the war, are now at the disposal of any nation. But if a new war broke out in the near future, gas warfare would be something quite different from what it was in the last war. The main reasons for this assertion are, first, that what might prove to be one of the most horribly effective of all gases, Lewisite, was discovered so late that it never came into actual use on a large scale; secondly, that new methods of projecting gas make it possible to get an area flooded with gas in concentrations hardly dreamt of before the last months of the last war—concentrations which would render quite inefficient some of the standard types of gas-mask then used; and thirdly, that the big industrial nations have behind them an experience in manufacturing poison gas which in any fresh war would make possible its use on a much greater scale.

In the circumstances, not to try to bring up the

efficiency of gas-masks as far as possible beyond the point where the last war left them, even leaving out of account the need for protecting the civilian population, is simply to invite overwhelming defeat in the next infantry battle

The same applies to mechanized transport like tanks, to aviation, to submarines, to machine-guns—in fact to every other weapon or branch of war. To neglect science and the improvements which arise from its application is to render your whole preparations for war inefficient and virtually useless

That being so, it is at least a slight comfort to recall some of the peace-time advantages which have come out of the applications of science to war-time needs. I am not advocating war as a method of securing scientific advance—that is, like the method described by Charles Lamb in the *Essays of Elia*—of burning your house down to get roast pork I just want to remind my readers of a fact—that there *is* something to set off on the credit side against all the horrors registered in the debit column when considering the effects of using scientific methods of waging war. Of course, this is really obvious—science is an all-round method, and any given scientific discovery is in itself ethically neutral. So you can no more prevent scientific work carried out for war purposes from having peace uses than you can help the general advance of peace-time science from throwing up facts and ideas which can be used for war. Let me remind you that none of the gases actually used in the last war was discovered in the search for a war gas. Mustard gas, for instance (together with a knowledge of all its unpleasant physiological effects), was discovered in the ordinary

routine of chemical exploration, some sixty years before the Great War broke out.

Let us look at a few instances where science in the service of war has conferred permanent gifts on peace. The most obvious example is aviation. It is quite certain that we should not be able to-day to fly at will from England and France to Central Africa, from Holland to the East Indies, from New York to San Francisco, if it had not been for the stimulus given by the war to aviation, in theory and practice—and, let me add, if it had not been for the heroism of aviators. Not only was aerodynamics thus stimulated, but in the search for lightness, an impetus was given to the search for light and strong metallic alloys which has given birth to what is virtually a new branch of metallurgy. In a similar way, the demands made on the toughness of armour-plate and on resistance to huge pressures in big guns, on accuracy in turbines (first used for naval purposes), have given us new heavy alloys and new standards of accuracy in steel manufacture which are proving of great service for all kinds of purposes.

Less spectacular, perhaps, than the stimulus of the war to aviation, but of far-reaching importance, was its stimulus to roadless transport. If it had not been for the tank, efficient caterpillar tractors would undoubtedly not by now have appeared on the peace-time scene, and we should be without the possibility I spoke of in an earlier chapter, of converting our barren moorlands into good grazing land, or perhaps of having large trains of caterpillar vehicles forging across the roadless expanses of Africa or Asia—this latter possibility one waiting for some enterprising

firm or Government to investigate and develop properly.

Then, such was the resistance of orthodox medicine to modern psychology that the whole crop of war neuroses were originally lumped together under the name *shell-shock*, as if their prime cause were mechanical, and not mental. If it had not been for the war, not only would the treatment of peace-time neurotics still be very backward, but general psychological theory would not stand where it does, or be able to make its valuable contributions to the modern outlook on crime, family life, the problems of sex, or education.

Another example is optical glass. There is a great demand in war for good lenses for field-glasses, range-finders, and all sorts of other instruments; and this demand has led to better lenses for peace-time purposes too.

Then we have the fact, rather curious at first sight, that research on gas-masks has led to a number of industrial improvements. This is because charcoal has been widely used in them to mop up poisonous substances out of the air. Charcoal will only do this when it is what is called "active," which means highly porous, so as to contain a great deal of internal surface, and also chemically clean. The study of the methods for activating it, and studying how it works when activated, have led to all sorts of improvements in dealing with gas mixtures—for instance, in separating one gas from another, in purifying commercial gas, and so on.

Then, quite recently an investigation was undertaken by the Medical Research Council with a view to preventing evil effects on industrial workers inhaling dust of

various kinds. Certain kinds of stone-dust are very bad for stone-workers, and, if used to prevent explosions in coal mines, very injurious to the miners. As the Chemical Defence Experimental Station at Porton is of necessity largely concerned with the effects of inhaling unpleasant substances, whether in the form of gases, vapour, smokes, or dusts, the staff there were able to give appreciable help to the Medical Research Council in some researches they undertook on this subject. (As an example of how easily misinterpretation may get to work, I may mention that this fact was recently cited by a very left-wing Labour periodical with the comment that "observations on diseases due to the inhalation of dust in miners have great bearing upon chemical warfare"—as if the only reason the Chemical Defence Station consented to undertake the work was for war purposes.)

These are a few examples of the benefits which may accrue for constructive work from science applied to destructive purposes. We should not belittle them, or pretend that they do not exist. But do not let us delude ourselves into thinking that they make more than a small offset to the damage and loss on the other side of the balance-sheet. And what is more to our present point, do not let us imagine that this is the only way to secure the constructive advance. If the amount of energy and money that goes into war research were focussed on to peace-time purposes, the results would be spectacular. They might not be the same in detail, but they would undoubtedly be far more important and far greater in volume than the present positive by-product of war research. To take but one example. If one half of the amount

annually spent on war research in Great Britain (which almost certainly is proportionately below the amount spent by a number of other nations) were devoted to the problem of how to make the nation healthier, the results would without question be astounding, and the next generation would be on a different level of physique and health from that of any previous generation in any country.

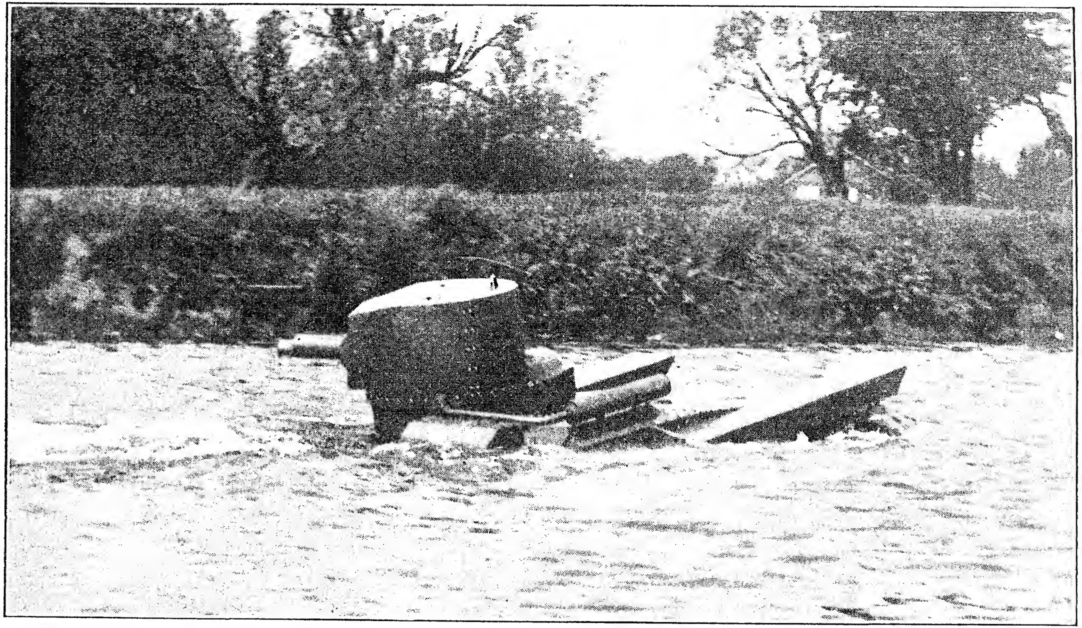
Research and its effects is less familiar to most people than concrete activities, so it is permissible to point the moral by reminding my readers that the U S A. in the two and a half years before the end of the war spent about four thousand million pounds in producing war equipment, and that this and the human effort behind it could have built the Panama Canal forty times over. (As a further contrast, the Government expenditure on slum clearance in this country proposed by the present Minister of Health is less than one hundred million pounds.)

But I must come back to my main point: the concern of science with war preparations. I have taken the attitude that if there is any danger of war at all, the preparations for it should be scientific, as otherwise they will merely be wasted. It is difficult to give many examples of the use of science in this field, since most of the work is, as a matter of national policy, kept rigorously secret, and requests to see it are met with a polite but categorical refusal. It is true that inspection of the publications of the Patents Office would reveal the existence of a number of obviously war-like inventions, but we still should not know the extent to which the Services were developing them or letting them lie.

It is, however, common knowledge that a great deal of army research has been concentrated on mechanization, notably with roadless vehicles, and that a great deal of naval research deals with fuel and engines to lend increased efficiency and speed to war vessels, and with metallurgy to increase the range and life of guns and the resistance of armour-plate.

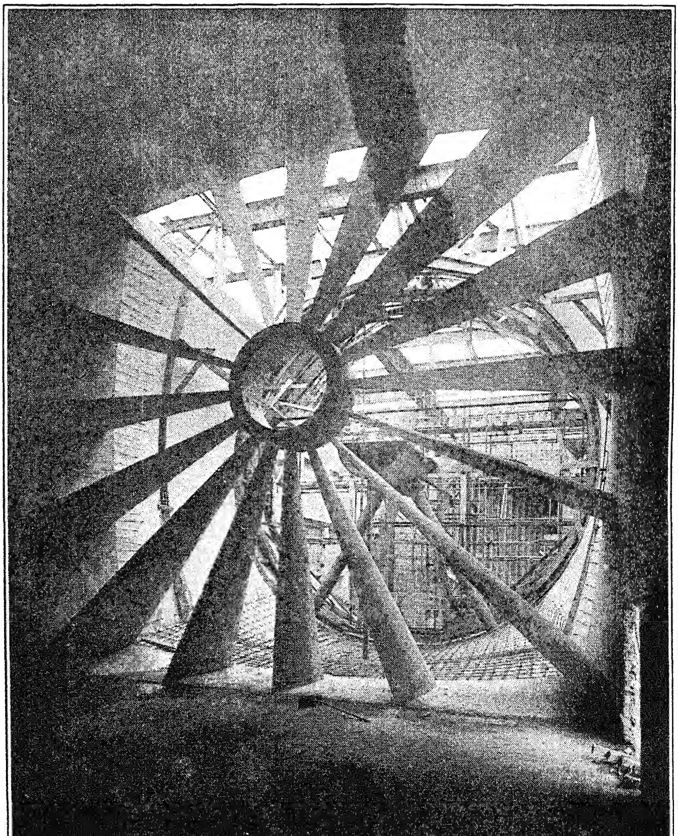
In gas warfare, developments have been kept extremely secret, but from the title of the responsible body—the Chemical Defence Committee—it may be safely conjectured that the main work has been concerned with improving gas-masks and other means of protection against gas—a conclusion supported by general chemical probability

In war aviation, of course, it is again common knowledge that both the speed and the carrying capacity of aircraft have been improved to a startling degree since the war: the speed is so high that it is nearing the physiological limit of the human organism (turning corners quickly at speeds of three hundred miles per hour and over leads to the brief loss of consciousness known as "blacking out"). Each increase in speed also brings us nearer to the aerodynamic limit of aircraft constructed on present principles; for with a plane travelling above a certain speed, the air ceases to give proper buoyancy, and becomes compressible, so that the effect on the plane would be rather like that of thick liquid mud in place of a nice hard surface for a motor-car. And as for carrying capacity, in America a year ago I was shown a new bombing plane which carried not only a central bomb weighing a ton, but also four other moderate-sized bombs—and, with it all, was capable of a speed



Keystone.

Developmental research for war purposes. Testing an amphibious tank made for the British Army, which is as much at home in water as on land. (*See* p. 162.)



Aeronautical research. The 24-foot horizontal wind-tunnel at Farnborough, under construction. In the foreground is the bearing for the driving fan, in the background a row of "air-straighteners." Some idea of its size may be gained from the broom seen lying on the floor. (*See* p. 165.)

of nearly two hundred miles per hour. It is also true that the stability of aircraft and the safety of flying have been enormously improved—I need only mention improved parachutes, slotted wings, automatic steering controls, wireless guidance, gyro compasses, and a general improvement in construction leading to much greater stability and much less danger of spin.

Aviation is also the one sphere in which it is possible to see a good deal of the research done for the fighting services—and that is because the results of the work are as important for peace as they are for war. It should not be forgotten that the Air Ministry has civil as well as military functions, so that, important as its research work is for war, it is equally essential for civil aviation. An obvious example of this is the autogiro, or windmill plane. The earlier models of this strange revolutionary new type of aircraft suffered from certain minor defects; but now that in the latest model the windmill can be started rotating from the engine, the rod carrying the windmill can be tilted at the will of the pilot, and the air-resistance has been lowered by doing away with wings and ailerons altogether, these defects have been overcome, and the research department of the Air Ministry are not only going to help with research, but propose to build new and larger models themselves, both for land and sea work. The new type of small autogiro will fly about as fast as an ordinary plane of the same weight, and with the same engine, but its stalling speed is only fifteen instead of about fifty miles an hour, it only needs about twenty yards to take off, and only five yards to land, against a very gentle breeze.

Apart from minor but still important considerations,

such as the possibility of hovering stationary over a site for purposes either of bomb-dropping or of photography, and, in seaplane types, the reduction of the speed, and therefore the danger, in taking off with a choppy sea running, the new autogiro opens up three absolutely fundamental new possibilities to aircraft: it makes it possible to operate with safety in mountainous regions; it makes it possible at least to think of privately-owned and privately-garaged aircraft in towns, and it enormously reduces the dangers of fog. This last is, at the moment at least, perhaps the most important Fog is the great enemy of air transport, more dangerous than gales or storms, so long as the need for a long landing run makes a big landing-ground and a clear view essential. But if you know you can land safely in the space of a garden lawn or a roadway, fog loses half—perhaps nine-tenths—of its terrors.

It will be of the extremest interest to see what happens in the competition, which is bound to become acute, between the autogiro and the ordinary aeroplane. In any case, however, the familiar winged type will doubtless continue to be used on a large scale for a long time—there is the momentum of long use and thorough testing behind it, not to mention that of the energy and capital tied up in its manufacture.

Much of its present serviceableness is due to patient research and scientific testing. I saw a good deal of this at the National Physical Laboratory, and had a talk with the Director of Research at the Air Ministry about the similar but larger-scale work going on at Farnborough.

The most spectacular work is in the wind-tunnels, both horizontal and vertical. A wind-tunnel is, simply

speaking, a tube through which air can be forced to make a wind of known speed, usually about 100 miles an hour, but in some special cases rising to 300 miles an hour and over. In the path of the wind is placed a small-scale model of the aeroplane to be tested. In general, the bigger the tunnel, the less difficulty there is in applying the results obtained on a model to actual full-size machines Most of the wind-tunnels at the N.P.L. are less than 10 feet across; but at Farnborough they have built a 24-foot tunnel, and in America there is one with a cross-section measuring 60 by 30 feet.

Another way of getting over the difficulty of translating results on a small-scale model into full-scale practice is to use compressed air (my readers will have to take my word for this fact—it would take too long to explain the reason). Accordingly, a new tunnel has been put up at the N.P.L. in which the wind is at a pressure of 25 atmospheres. This is a very impressive object to look at, being built of a series of the biggest rolled forgings ever made, each weighing 24 tons, bolted together. The steel wall is about 2½ inches thick. Some most ingenious gadgets permit the model to be manipulated and the records to be read from outside the tunnel.

By work such as this, striking improvements have been made, largely in the way of reducing air-resistance, and therefore, of course, of improving the speed and range of aircraft, but also in the way of increasing stability.

As regards stability, however, the most intriguing research is going on at Farnborough in the new vertical wind-tunnel, in which a model, actually flying freely, is supported by an upward current of air. This is

being especially useful in studying the question of spin, which so far has proved too complex for proper mathematical analysis. Sometimes, after the models are flying gaily, their controls are altered by a delayed-action switch which was set beforehand, so as to study the effects of sudden movements during flight. Already the work has led to certain valuable changes in design.

So I could go on, but I have no space. I would only like to emphasize again that the great bulk of the research work of the Air Ministry is, in the present state of aviation, inevitably devoted to the general improvement of aircraft, in regard to speed, efficiency, range, carrying capacity, stability, reduction of noise, and general safety and comfort, and that this cannot help being equally useful to civil as to military aviation—as indeed it is intended to be.

But besides the use of science in making war preparations efficient from the technical military point of view, it can help to increase their efficiency from another angle—low cost to the nation. The secrecy of war research makes it impossible to apply the ordinary public checks on its efficiency, item by item; but it is possible even for a layman to give some opinions on its organization according to certain general principles. One of these is that in a research programme, competing interests should be harmonized so far as possible in a central organization; another is that arrangements for expenditure should be as flexible as possible. Let us see how these two points apply in war research. In this field, the needs of land warfare, sea warfare, and air warfare are in a certain real sense competing interests so long as there are three separate Depart-

ments of State dealing with them. This is not the place, nor have I the knowledge, to debate whether the conflict of interests can best be resolved by merging the three in a single Ministry of Defence—as most people know, there are many pros and cons to this question —or by the present methods, which many people find unsatisfactory, of having a rather exiguous Committee of Imperial Defence, coupled with periodical meetings between the Chiefs of Staff of the different Services. Here we are concerned only with the relation of research to the problem, and it may be suggested that the establishment of a War Services Research Council, covering the whole field of science in its relation to warfare, and analogous to the D S.I.R. in the field of industry or the Medical Research Council in the field of health, would probably be advantageous. At the moment many people feel that the cost of war research is low in proportion to the amount of money spent on the upkeep of possibly obsolescent armaments, but high in proportion to its ultimate efficiency, and that proper organization could much increase its money's worth to the nation.

If such a Council were established, it would not only be able to take research out of its departmental pigeon-holes and see it more readily in relation to the totality of war needs, but—and this brings me to my second point—it would probably be a better instrument of financial control. For, to be fully efficient, it should be organized somewhat after the fashion of the Medical Research Council, with a lump sum voted to it for its work, and practically complete control over the detailed allocations of this sum to this or that kind of research. This would allow greater flexibility in

changing over from one project or type of research to another, if scientific progress demanded it.

To go back to my example of battleships *versus* aircraft, the question of relative cost, and therefore of the total cost of the national premium we pay on account of war, also enters into this problem—you can make something like a thousand aeroplanes for the cost of one battleship. But I see that I am straying out of the field of science into that of strategy and policy, and as the amateur strategist is generally wrong and always a great bore, I will stray no further, and merely once more emphasize that we need not only science in research, but also scientific method in the organization of research.

So far, then, for the first half of my realistic principle—the application of science in the interest of war efficiency. Now I come to its second half—the application of science to make war as unlikely as possible: science applied to disarmament, if you like, as opposed to science applied to armament. This has received comparatively little attention, in spite of its great practical importance.

So far as I know, two main approaches have been made towards it, one technical, the other psychological. The technical approach is best put forward in Major Lefebure's book *Scientific Disarmament*. He points out that the making of armaments in the large quantities needed for modern war involves a series of steps—a development, to use a biological phrase—which inevitably consumes a certain amount of time, and that this, further, is a good deal longer than most people suppose. This time-lag applies not only to cases in which factories and works are converted from making

some peace-time product, but also, though to rather a lesser extent, to the mere expansion of existing works. We may call the one *conversion* lag, the other *expansion* lag. In Lefebure's book numerous examples are given of conversion lag, for such various products as shells, poison gas, small arms, and aeroplanes. In general, we may say that the lag, even under the urgent stimulus of war needs, varies from a few months to a year and a half, with an average of between six months and a year. This is due to the time consumed in designing new machines and gauges, in training workers in the new processes, and in the rigorous testing which is necessary at every stage in the proceedings

The suggestion is therefore made that disarmament can be scientifically studied as a technical problem, by accumulating facts about this time-lag for different kinds of armament; and that it can then be scientifically controlled by having the manufacture of as many armaments as possible either prohibited or else regulated to small amounts during peace-time; and also by insisting, wherever a peace-time product (such as an aeroplane) can be converted to war purposes, that its design shall be such as to make the conversion more difficult—instead of as easy as possible, as is the avowed aim of certain nations at the moment with regard to aeroplanes.

Another point which comes up here is the attitude of scientists themselves to helping in war preparations. At the moment there is nothing which you could call a professional attitude of science on the question. At one end are those who under no circumstances would help. This is completely logical, provided that they

would become conscientious objectors in the event of war At the other end are those of the " my-country-right-or-wrong " school, who are again completely logical, provided that they really do believe that internationalism is always nonsense, and that their horizon should be bounded by that of their nation. But the bulk of scientists, being scientists, cannot help feeling that they have some international duties to humanity at large, and, being citizens, that they have some national duties to their country. For the most part, however, they have not clarified the resultant conflict. Probably most of them would dislike undertaking certain kinds of research, such as work on new forms of poison gas, or on bacterial warfare, in peace-time, and yet would do just as they were told in war-time. But a feeling of discomfort, of conflicting loyalties, remains.

If it were accepted as part of the scientist's general code that research work in connection with general war needs was always legitimate, but that it was illegitimate to do research on agencies prohibited by international agreement, or to help in the large-scale production of armaments in peace-time, the situation would be cleared up a great deal. That it is not impossible for a profession to have a professional attitude of high standard, and on the whole to live up to it, is shown by medicine. It should not be impossible for science; and the right attitude on the part of the scientific profession would be a small but definite help in preventing war.

By these various means you would ensure that there was a serious time-lag between the declaration of war and the time when war could be carried

out on a really large-scale modern basis, with all its resources of cubic miles of gas, millions of shells, thousands of aeroplanes, and the rest And this would give a real opportunity for passions to cool and peaceful methods to find a settlement. According to this view, the best guarantee against sudden aggression by an over-prepared nation, and the best chance of averting a prolonged conflict, is to be found in the agreed reduction or prohibition of the actual large-scale manufacture of armaments in peace-time, for this is the one link in the chain where preparations could not possibly be concealed, and the one prohibition which ensures a big time-lag before really large-scale warfare could be waged.

This is a real approach to the problem of disarmament, by making a scientific analysis of the process of armament, instead, as is done in most disarmament proposals, of thinking in terms of politics and prestige; and as such it deserves careful consideration.

The other approach, the psychological one, is more remote—indeed, more utopian. It is none the less interesting. Certain psychologists of the modern school have pointed out that one of the eternal conflicts imposed upon human nature is that between our destructive, angry, violent impulses on the one side, and on the other the demands of family and social life for restraint and ordered living. The conflict begins, inevitably, in the nursery—the yelling baby, the child in a tantrums—but its effects may last throughout life. If the impulses to anger and violence are not properly educated, but merely repressed into an uneasy imprisonment in the sub-conscious mind, they will continue to demand an outlet, and will

succeed in finding one by devious channels. The results are sometimes surprising, as when you find certain brands of pacifists and anti-vivisectionists, who presumably should be of a kindly disposition, publicly asking for the most unpleasant penalties and punishments to be inflicted on their opponents.

But a more usual solution for the conflict is in the framework of patriotism—whether the patriotism of a class, a political party, a race, or a nation—and the repressed impulses to violence find their outlet in abusing or attacking the other fellow: the one who happens to belong to a different class, party, race, or nation.

The psychologist's contention is that so long as this fund of repressed destructive impulse exists among a large section of the population, it will continue to demand an outlet; and if nationalism makes war the obvious outlet, the danger of war is thereby increased. They further contend that our destructive impulses need not be repressed in this crude way, with such unfortunate results; and that if children were differently brought up, with less repressive discipline, more outlets for self-expression, our destructive urges would be properly harnessed with the rest of the team of human impulses, and the fund of repressed and therefore dangerous emotion would be enormously reduced. In other words, scientific anti-war measures should begin in the nursery and the school.

There may be a good deal of speculation mixed up in this argument, but there is undoubtedly some element of truth; equally undoubtedly, there is no research being undertaken on the subject. One would think that if the governments of the world were thinking of

disarmament in the same hard-headed (but open-handed) way as they think about armament, they would have set on foot a very considerable amount of scientific research into the causes of war in general, the risks of war in the modern world, and the measures to be adopted for reducing these risks But apart from a few inquiries on certain technical aspects of armament production, nothing, so far as I am aware, has been done, either at Geneva or by separate nations. The result is to make disarmament discussion about as useless as would be a discussion on public health by those ignorant of physiology, or on eugenics by a body of persons unacquainted with the laws of heredity.

However, this brings me to another point. The psychologists may be right in supposing that the emotional gunpowder, so to speak, for the explosion of war, is generated by conflict and repression, but we must not forget that there is a large and increasing school of thought which sees in economic forces the essential causes of war. At the moment, they say, the combination of the profit motive in business with nationalist ideas in politics has imposed on the world an economic nationalism which must, in their view, lead to war if it is not checked or altered.

Now, this view is by no means inconsistent with the view put forward by the psychologists The fund of emotional explosive may exist and may be very dangerous; but it could not lead to war in the ordinary sense, unless the explosion was canalized, so to speak, along nationalist channels. In a different type of political world you could still have certain kinds of war—class wars, police wars against recalcitrant tribes, and so on—but not the national type of war, which

involves setting in the field the maximum number of combatants armed with weapons of the maximum degree of effectiveness

So here we are, back, as in previous chapters, in the economic and political sphere Here again, science by itself cannot, by its very nature, take us the whole way to a solution. It can gradually change the situation—for instance, as suggested by such students of strategy as Liddell Hart, the development of air warfare may have introduced such new conditions that mass trench-warfare of the type made familiar by the last war would never again come into existence—because the process of mass mobilization would afford such targets to bombing aircraft that it could never be completed, and in the regions behind the war frontier an alarming state of chaos would result. If so, war may become more professional again, though on a new plane of scientific and technical efficiency, and aimed as much at civilians and at economic objectives as at the enemy's armed forces. Or, indeed, eventually it might well come to pass that scientific devices will make warfare so intensely horrible as to bring about an overwhelming pressure towards peace and disarmament. Opinions differ as to whether war will paralyse itself or commit suicide, or if it will manage to destroy civilization first. Meanwhile, however, science can only operate in the framework of existing conditions.

But if existing conditions—in this case economic nationalism—inevitably head us towards war, what then? The answer, I take it, is to try to apply the scientific spirit to the study of this question too. It is very far from easy, as so many factors are involved,

and also so many feelings and so many vested interests; but it is at least possible to attempt a dispassionate survey. And if that survey shows that the economic nationalism of sovereign states makes war easier, the remedy would seem to be clear—to take steps to subordinate certain of the sovereign rights of nationalist states to international authority. The most obvious case is in the air. With an international system of civil aviation, and restriction or prohibition of the manufacture of aeroplanes for war, save for the purposes of an international air police, both the risk of war and its possible horrors would be cut in half at one stroke. For this, however, a surrender by national states of certain of their existing rights would be necessary.

Other authorities think that internationalization of civil flying would be too difficult, and would prefer the establishment of a general super-national or international police force. That too would, of course, demand some surrender of sovereign rights by nations. This, indeed, is the logic of the case—either keep your sovereign rights and your nationalist patriotism intact and live in a condition of maximum insecurity and risk of war, or increase your security and cut down your war risk at the cost of some of these sovereign rights.

Thus our conclusion is that science *can* enter into the problem of disarmament; but that to exert any considerable effect it must wait upon change in political outlook and practice.

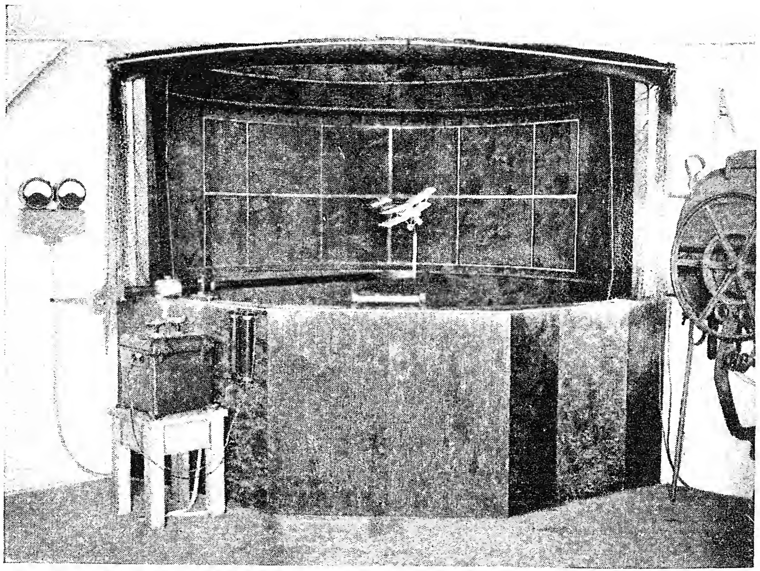
CHAPTER X

MAN AND SOCIETY

MAN and Society—I chose the title for want of a better one. In this chapter I want to deal with the human factor in affairs and what science is or is not doing about this. I shall begin with something quite straightforward—the work being done in certain quarters to prevent accidents and reduce industrial disease among workers. This leads on naturally to some discussion of what is generally called industrial psychology—discovering how work may be made both less fatiguing and more efficient (the efficiency being measured in relation to the worker as well as to the employer) and studying questions such as proneness to accident.

This, again, leads on to the problems of vocational guidance—finding the right kind of job for a person; and vocational selection—finding the right kind of person for a job. In many cases, unfitness, however estimated, turns out to be due to some psychological trouble, so the next step is to some consideration of psychology and what it is doing.

Modern psychology is a very young science. Thanks primarily to the genius of Freud, it enables us to see ourselves in a new perspective, with our conscious thoughts and beliefs inevitably coloured by our subconscious mind and the repressed impulses in it. By realizing this fact and attempting to discount it, we



Aeronautical research. A model aeroplane being tested for spin, flying freely in an upward air current in the 12-foot vertical air-tunnel at Farnborough. (*See* p. 165.)

From *New Methods of Research in Aeronautics*, by H. E. Wimperis.

By courtesy of the Royal Aeronautical Society.

The results of experimental testing: a type of special hard hat recommended by the Safety in Mines Research Board to protect miners from falls of roof. This miner had his life saved by his hat. (*See* p. 179).

From the Safety in Mines Research Board Eleventh Annual Report.

By permission of the Controller of H.M. Stationery Office.

arrive at a quite new outlook in regard to education, to penal reform, to family relationships, to mental disease, and many other fields But in all these fields it is not possible to think only in terms of individual psychology. So we are led on to the study of social psychology—the way in which the structure of society influences our minds, usually without our being aware of the fact. Here all kinds of most important questions crop up which have as yet hardly been tackled seriously, such as the good side of propaganda, the kindling of large-scale group enthusiasms for other than war or party purposes, and so on

In fact, the more we look at the matter, the more we see that in every department of life psychological study and approach could be of the utmost importance; yet the number of professional psychologists in the country is ridiculously low compared to that of trained workers in any other big branch of science, and in general psychology is sadly neglected.

Perhaps the most important single fact which comes out of psychological study is this—that human nature is not unchangeable, as so many people believe, but, on the contrary, is plastic within very wide limits.

But psychology, individual or social, will only take us a certain distance. We can also apply science to the general study of society as an organism; that is sociology. I shall not be able here to say much about sociology, except to point out that if we want to control the development of society in an efficient, orderly way, we had better trust to science instead of to so-called common-sense opinion, blind economic forces, politics, or revolutions.

Finally, there is another line I want to pursue. One

of the things that psychological testing brings out is the amount of difference between individuals When we follow this up, we find that a great many of these differences are inherent, inborn. And this leads on naturally to the question of eugenics, by means of which we may eventually hope to change the limits now set to human nature. So here we end with the idea of man's control, through science, not of the materials and forces around him, but of his own nature and its expression. That is a great deal of ground to cover in a single chapter, so I shall have to be brief with each of my subjects.

First, then, the welfare of the worker. It is worth remembering that the Factory Acts have just celebrated their centenary, and that this hundred years of legislation, accompanied by the supervision of Government Factory Inspectors, has done an enormous amount to improve conditions of work and do away with the old shameful state of affairs in which there was no regulation of hours, no standard rates of wages, no restriction as to sex or age of workers, when even small children worked in factories, sometimes for twelve hours a day.

But all this, though extremely valuable, has meant for the most part the correction of obvious abuses, and science has not been called in to any great extent. One very special institution, however, which I visited is concerned quite definitely to use science in order to improve the conditions of one particular set of workers —the coal-miners This is the Safety in Mines Research Board, with its main laboratory at Sheffield, and another, where large-scale work goes on, out at Buxton. Though the main laboratory is among the buildings of Sheffield University, the Board is quite

independent, and is supported out of the Miners' Welfare Fund, which is raised by a levy of a penny a ton on all the coal mined in this country.[1] Do not imagine, however, that all the research on safety and health in mines is done here . a good deal is carried out in the Mining Departments of various Universities, one of which I also visited, at Birmingham.

Let me give a few examples of the sort of work that is going on. At Sheffield I saw a Davy safety lamp of the ordinary pattern, but bigger and giving out ten times as much light; and at Birmingham a new electric safety-lamp for roof lighting—a most ingenious bit of electrical engineering designed to secure small size, and to prevent all danger of a spark, with its possibility of an explosion, if anything goes wrong. These new lamps are both attempts to get rid of that horrid disease, miner's nystagmus, which involves the failure of the central region of the eye, and affects a large proportion of the men at the coal face. As it is generally accompanied by headaches and depression, it is pretty serious Research has shown it to be due entirely to insufficient light; and in a few years we ought to see the last of it.

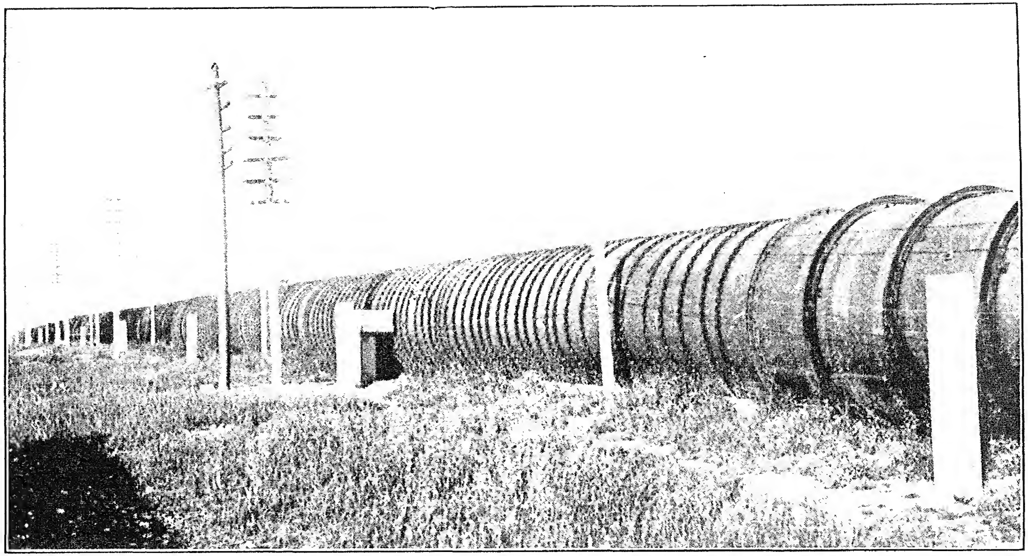
Then there was the discovery made by the head of the department at Birmingham, that miner's cramp, another unpleasant disease of coal-mining, was due to loss of salt. Miners sweat a great deal with their hard work in a hot atmosphere, and when you sweat, salt comes out of your blood as well as water, until, if you sweat too much, the salt in your blood falls to a danger point and muscular cramps are the result.

[1] Since this was written, Parliament has unfortunately seen seen fit to reduce the levy to ½*d*. per ton.

Once this chain of causes had been discovered, the remedy was obvious—to drink salty water instead of ordinary water—and also efficacious.

Then a great deal of work is being done at Sheffield on the prevention of explosions—for instance, fundamental studies of what really happens in a flame and in the rapidly travelling flame we call an explosion. These are building up almost a new little branch of pure science, and also showing the way to introduce new safety measures—such as coating explosive cartridges with sodium bicarbonate, which makes a protective blanket at the moment of firing for just long enough to prevent the charge starting an explosion even if firedamp is around; or rigging up gadgets which utilize the heat of an explosion once it has started, to operate a dust exploder which throws up a barrage of fine dust and so stops the explosion from travelling further. Much research is also being carried out on the best types of dust to use in the ordinary way for preventing the spread of explosions, on the prevention of falls of roof, on detonators for firedamp, and many other problems.

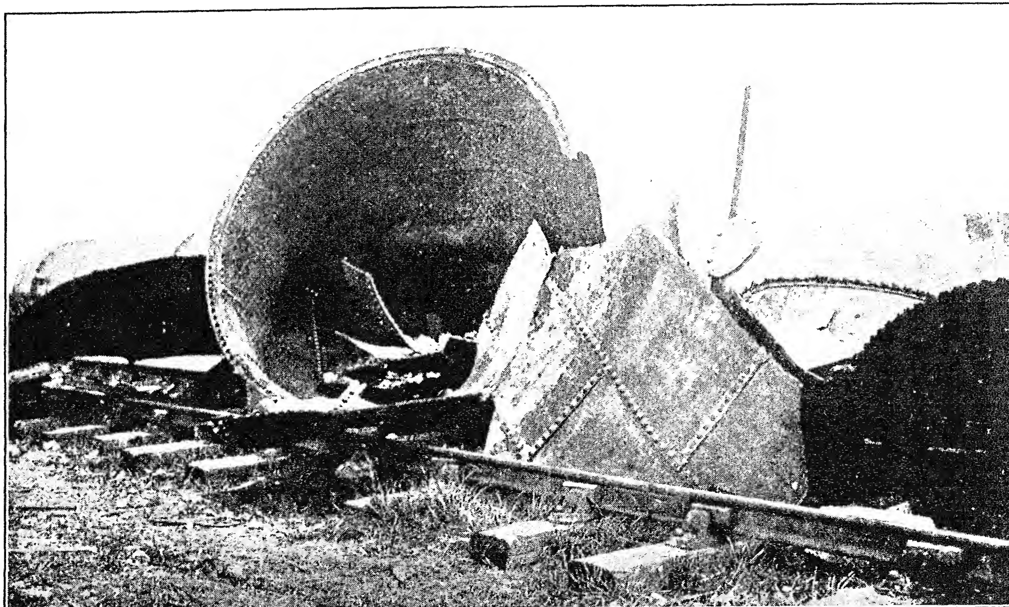
Then there is the interesting research being done by the Government, through the Industrial Health Research Board under the Medical Research Council. One of their most interesting lines of study concerns what is called occupational neurosis—neurasthenia, worry, nervous breakdown, and so on, caused by the conditions of work. This is extending the idea of industrial disease to diseases of the mind. It is going to be very important from the point of view of better health for the workers, and also from that of the employer in reducing wasteful labour turnover and absence through sickness.



Large-scale research on safety in coal-mines. A long gallery of old boiler shells built in 1928 at Altofts in Yorkshire to discover how explosions travel. (*See* p. 180.)

From *Safety in Coal Mines : Some Problems of Research*, issued by the Safety in Mines Research Board.

By permission of the Controller of H.M. Stationery Office.



Part of the same gallery as that shown in the preceding illustration, after an experimental explosion, which showed that serious explosions that travelled long distances could arise from coal dust alone without gas. (*See* p. 180.)

From *Safety in Coal Mines : Some Problems of Research*, issued by the Safety in Mines Research Board.

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Then there are important studies on the effect of noise on workers' comfort and output. (In passing, it is interesting to find how many different institutions are separately studying the noise problem. If research were organized primarily from the angle of the worker, or from that of the consumer, in the shape of the general public, instead of primarily from that of the producer, we would expect to find a centralized Noise Research Station instead of these sporadic bits of work.)

Lighting, heating, ventilation, dust, vibration—these are other questions being studied along similar lines, and there are special researches like those into the effects of deep diving on the physiology of the diver.

Some of the work is farmed out—for instance, to the Psychology Laboratory in Manchester University, which I visited earlier. This is one of the few University Departments of Psychology where full-scale tests on industrial workers under industrial conditions can be carried out.

Industrial health links on closely with what is generally called Industrial Psychology. This, however, is something broader. It, too, is dealing with the human factor in industry, but instead of dealing primarily with industrial disease and the prevention of ill health, it sets itself the more positive task of finding out how to promote greater efficiency in all ways other than technical improvement of machinery and processes. To do this, it all the time stresses the necessity of not thinking of work in purely mechanical terms, but in terms of a co-operation between a machine and a human organism. The machine works mechanically; the human organism does not, but has its own quite different way of working, its own feelings, its fears and its

ideals, which also must be studied if the co-operation is to be fruitful. Considering the importance of the field, it is really absurd that there are only two institutions in the country which are concerned with it, and only one exclusively concerned; and that this latter is a private body which, though it receives some grants for pure research, must go into commerce and attempt to make money in order to carry on a full programme. One of the two institutions is the Industrial Health Research Board, some of the work of which I have just been describing. The other, on a private basis, is the National Institute of Industrial Psychology in Aldwych. It is interesting to find that the work of the two bodies is often complementary. For instance, one piece of research undertaken by the Psychology Department at Manchester for the I.H.R.B. showed that training in one kind of simple manual work was not necessarily of the least help in learning dexterity in other manual operations. Then, however, another piece of research undertaken at the National Institute made it clear that while mere practice in dexterity had no effect, real training in the ideas and principles underlying dexterity does definitely help in learning a fairly wide range of other manual operations. These results obviously have a bearing on the methods of training to be adopted in factories.

I went over the National Institute, and must try to describe a few examples of its work, to give an idea of what it is aiming at. One big research here is concerned with the psychological factors entering into motor-driving. You sit in a model of a driving-seat, press a button, and suddenly the picture of a road begins to unroll before you on a screen. You have to steer as

you would if actually driving a car, and a record of the track you take is automatically recorded on a map of the route. I at first thought the picture was a projected film, but really it is produced by a delightfully Heath Robinson (though efficient) gadget—an actual model of a road with hedges, corners, crossings and so on, which rotates all the time; a stationary light in the middle projects the picture on to the screen. You can make the course more difficult by putting model road-up signs, pedestrians, or other obstacles on to it.

Another test, carried out in another room, is designed to discover your capacities for concentration. While you are engaged on a test which demands looking in one direction, a miniature film is projected on to a screen, tantalizingly just within your range of direct vision. The ratio of your performances with and without the film gives some measure of your liability to be distracted by incidents on the road while driving. There were a number of other tests, which made me feel that the director of the Institute was probably right when he claimed that the problem of the roads was more than half psychological, and that it would be an excellent thing if the Ministry of Transport were to have a few good psychologists on its staff.

The Institute's commercial work includes the advising of firms as to improvements which could be made in lay-out, lighting, measures for saving waste of movements or of energy by operatives in carrying out a process, and so on. Such work has often been criticized as being only in the employers' interest and being used merely to speed up output to the limit of the worker's physiological capacities. That it could be so abused is obvious, but it is also obvious that if so

abused it will eventually defeat its own aims. The founder of motion-study methods, the American engineer Taylor, did introduce a number of harsh features into the system he devised However, this was precisely because he was an engineer, not a psychologist, and did not take the men's psychological reactions sufficiently into consideration—with the result that his schemes in their original form would not work.

If properly carried out, work of this sort will not only pay the employer, but will also help the employees by reducing the fatigue of their jobs, and often by making it possible for them to earn more

Let me give two exceedingly simple examples. The Institute was called in to advise about some work involving the sorting of black-currants The investigator found that the currants were handed out to the girls in one-stone lots, and that this amount was so big that it had a discouraging effect. When the size of the lot was reduced to half a stone, the girls could *see* the end of the particular job, so to speak, and the result was a doubling of output, together with bigger earnings, and a greater feeling of satisfaction among the girls

Then general research has shown the value of rhythm in reducing the fatigue and monotony of purely repetitive work of a very simple sort. When this was tried out with workers loading a mechanical conveyer, it was found that putting the boxes on in groups, several at a time quickly, with pauses between, increased the speed of loading and yet reduced the worker's feeling of fatigue. This is an excellent illustration of the value of psychology in industry. The common-sense view was that regular timing would give the best

results: the industrial psychologist insists on a biological view which takes into account the facts of human make-up as well as the view of common-sense, which happens to be based on a mechanical outlook.

By the way, I saw one striking example last spring in Holland of the effect of good working conditions on workpeople, in the beautiful new factory, built largely of steel and glass, a triumph of functionalist architecture, recently put up by the cocoa and coffee firm of Van Nelle. When they moved out from their old quarters, a dark antiquated building in the heart of Rotterdam, they had all their operatives weighed. A year later they were weighed again. Not one had lost weight; the average gain was over 4 lbs., and, so one of the directors told me, the men had a different, more contented look and were more efficient.

The ideal state of affairs would be one in which such schemes should be undertaken compulsorily, by Government institutions, with advisers from among employers, workers, and managerial staff. Meanwhile the National Institute and the Industrial Health Research Board are doing useful pioneer work.

But in some ways the most interesting things the Institute is doing concern vocational guidance and vocational selection. They look into the cases of boys and girls leaving school, and provide guidance as to the type of job they ought to go into. The kind of work may be entirely different from what the children themselves say they want to do, or from what their parents suggest.

An experiment along these lines was recently carried out in conjunction with the education authorities in Birmingham. Half of a group of children were advised

in the ordinary way at the Conferences on choice of employment attached to the school; the other half were, in addition, tested by specially trained workers. The tests concerned manual dexterity, mechanical ability, clerical ability, performance tests with concrete problems, and ordinary intelligence tests. Furthermore, special temperament charts were constructed for each child, to include estimates of such qualities as initiative, perseverance, and so on. The type of jobs recommended varied from clerical posts to routine factory work, from page-boy to skilled apprentice.

The results as checked by a follow-up investigation were pretty conclusive. The children who had been specially tested and had followed the tester's advice proved to have been much the most satisfactorily placed, as judged by the length of time the first job was held, by the proportion who continued in the same job throughout the period, by the opinion of the employers, and by the opinion of the children themselves The tested children who took jobs against the tester's advice were the least satisfactorily placed, with the untested children intermediate.

It is interesting to find that unsatisfactory results arise not only from round pegs in square holes—such as workers in clerical posts whose real gift is manual dexterity: not only from small pegs in big holes—children taking on jobs beyond their real powers: but also from big pegs in small holes—workers who get discontented because their job does not give scope for their abilities or their initiative.

The same sort of tests, of course, can be applied from the employer's point of view, to select the best-suited from among a number of applicants for a particular

job. A good deal of this is being done by the Institute, and also by the Industrial Health Research Board, who have, for instance, been quite successful in prophesying the suitability of candidates for driving tanks in the Tank Corps : similar work is going on as regards tests for suitability for Army signallers, aviators, and so on.

These methods are still in their infancy, but it seems certain that in them we have a most valuable addition to the ordinary methods of judging candidates by examination results or on a hasty interview, and that as they are improved and more widely adopted, the country will profit a great deal from the reduction of labour turnover, from general increase in efficiency, and, most of all in the long run, from the greater contentment and satisfaction which come from having work in accordance with your aptitudes and abilities instead of in conflict with them. It may also be suggested that in the Planned State of the future there will be tests for employers as well as for employed. As it is, doctors and lawyers and other professional men have to pass stiff examinations before being admitted to practise their profession, and in the Army and the Navy, examinations recur periodically during an officer's career. We may expect that the business man of the future will have to face the same sort of ordeal, with some psychological tests thrown in.

Vocational guidance brings the industrial psychologist into contact with problems of family life. It is surprising how often it turns out that a boy's parents have no views as to what he should become, or, when they do have views, how often these are at

variance with the real bent of the boy's character and aptitude. And in quite a number of cases a conflict is revealed It may be a conflict with obvious motives, as when the parents want a child to go into a poor sort of job because it will bring in money at once, and the child wants something better, or the motives may be deep below the surface, and the conflict date back to infancy and be due to such causes as obscure jealousy between father and son, accentuated maybe by over-fondness on the part of the mother.

With this sort of problem industrial psychology does not attempt to deal; but there are agencies for dealing with it, some on a very large scale. The London County Council used to have an official holding the special post of Psychologist. He was familiar to wireless listeners as Dr. Cyril Burt. One of his varied jobs was to study the children who were backward at school, and among these the children whose backwardness depended on neurosis made a well-marked type. Now Dr. Burt has become Professor in London University the L.C.C. have not filled the post, but carry on some of the work by sending such children to the Child Guidance Clinic in Islington, or the Institute of Medical Psychology in Bloomsbury.

The results are often startling. A great many children, it turns out, are not only backward in work and largely wasting their time at school, but also unhappy and headed towards graver troubles, such as neurosis, in the years to come, just because they are in a mental tangle. Not only this, but the mental tangle can often be set straight, or at least straighter, by taking quite simple steps in consultation with the child's parents and teachers.

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Industrial psychology : a test for weavers. The girl has to thread a wire through a series of eyelets; this involves making movements like those employed in picking up a dropped thread. (*See* p. 182.)

Industrial psychology: a test for divided attention. The boy being tested is a would-be engineering apprentice. He has to tap with one hand while inserting pegs in a board with the other. From time to time the examiner switches on the light, when the candidate must stop pegging and switch it off. His reactions are timed throughout. (*See* p. 186.)

By courtesy of the National Institute of Industrial Psychology.

We all want to remedy physical deformity and stunted growth. Mental deformity and stunted mental growth are in many ways more serious—only they do not strike us so forcibly, because we cannot *see* them Now that psychology is helping us to realize their extent we ought to take steps to have Child Guidance Clinics all over the country

This is, I think, the place to put in a word about the fundamentally new ideas to which the rapid development of psychological science is leading us. These ideas meet with a great deal of opposition, partly because they are at variance with traditional views of religion, or morality, or political philosophy, but perhaps still more because they *inevitably* come up against deep-rooted resistances, all the stronger for being irrational, and indeed often unconscious, in the mind of the average man and woman.

I suppose almost all scientists, however much they might disagree with Freud in respect of detail or even principle, would unite in saying that he has had more influence than any other man on the recent rapid growth of psychology. His great contributions to the science are, first, that he has insisted on a dynamic view of human behaviour and mental life, as the resultants of a series of urges or drives, harnessed to a series of goals or aims, which push and pull the human being in various directions. Reason is not an impelling force, and all too rarely a guiding hand: in the majority of cases it is just engaged in finding reasons—more or less rational excuses, if you like—for the actions to which we find ourselves impelled. Secondly, Freud, more than anyone else, has pointed out the importance of the unconscious or subconscious mind.

In particular, he has shown how impulses may be repressed into the unconscious, and yet may go on exerting their influence. In the developing human mind, a series of conflicts inevitably takes place—between selfish and altruistic urges, between the impulses to senseless violence and the demands of ordered living, between the crude sex impulse and the accepted standards of society This series of conflicts, also inevitably, begins in infancy; and, especially in early life, conflicts may be solved by what is technically called repression, in which impulses which have painful consequences are sat upon and squashed—thrust altogether out of conscious life But—and this is the point—they are still alive and active in their imprisonment, and manage to express themselves in all sorts of roundabout ways, which accounts for a great deal of the curious behaviour of you and me and our fellow human beings—behaviour that undoubtedly would seem very odd and irrational to a scientist from another planet.

Let me give one or two examples. Repressed impulses to anger and violence may ally themselves with the repressing forces of the mind, and make them harsh and cruel. This may show itself in the form of an over-strict conscience, or, more often, in the form of a moral attitude which makes you very indignant—about other people's lapses. The indignation may be specially reserved for lapses in the particular sphere of conduct where you yourself have practised the most thorough repression; this is very common as regards sex matters. Or it may be reserved for the sphere about which you happen to harbour a strong and often unconscious fear; this is well seen in the

violent attitude of property-owners to petty theft by members of what they like to call "the lower orders." Undue sense of sin, inferiority complex, persecution mania, imaginary invalidism, and exaggerated lust of power—these and many other manifestations of human nature can also be traced back to repressions arising out of conflict.

Then, partly from this side of psychology, partly from others, comes the assurance that human temperament and attitude can be modified much more than is usually supposed The old dictum "you cannot change human nature" has lost a great deal of its meaning. It is true that you cannot change it beyond the limits appointed by heredity—but those limits are extremely wide. You can change the growth of a tree in your garden—stunt it, make it leaf, encourage its growth and general leafiness, make it fruit heavily, train it on an espalier, and so on; so the growth of the mind can be changed, and changed more radically than that of a tree. What is really being changed, of course, is not human nature itself, but its expression. However, what people have thought was human nature has been only a particular, rather usual, rather crudely-organized set of its expressions. Psychology is only at the beginning of things as far as controlling the growth of human nature is concerned; but it sees that it can be done.

Apparently, perhaps, opposed to this idea, but really complementary to it, is the realization of the amount of innate differences between individuals. The more psychology has been used in practice, the more evidence it has found of individual differences. In education, intelligence tests show the existence of very big differ-

ences in native intelligence among children. In industrial psychology, vocational tests reveal equally great differences, in temperament, in special bent such as mechanical, artistic, or literary aptitude, even in basic qualities such as quick reaction, or the discriminating powers of eye and ear in seeing and hearing. Similarly, other tests reveal that some people are what is called "accident-prone"—their make-up is such that they are much more likely to be involved in accidents than the average. Of course, the proneness of a lorry driver to motor accidents, of a machine operative to have trouble with machinery, or of a waitress to drop trays, are not all due to identical causes: the important thing is that accident-proneness exists. This links up with a modern tendency of medicine, which is finding marked innate differences in regard to predisposition to disease; and with the whole science of heredity, which makes it clear that you must *expect* marked innate differences to occur among the population in regard to every conceivable characteristic.

Thus psychology is showing us the surprising degree of inherent differences between different individual human minds; it is also showing how wide are the limits within which any given human mind can be moulded during its growth; and, finally, it is showing that one of the commonest incidents during the growth of minds is a conflict of impulses, with final repression of one set into the unconscious, where it continues to influence our conscious thoughts and feelings without our realizing it—with the result, in fact, that our knowledge about our own minds and motives is both incomplete and incorrect, and that the more

strongly we feel about an opinion, the more likely it is that we are holding it on irrational grounds

Let us see how all this applies to social problems. First there is the law. Here I had the opportunity of an interesting talk with Mr. Hamblin Smith, who was a prison doctor for over thirty years, and has consistently tried to apply psychological principles to the cases he has been called on to deal with. He confirmed the belief I had already gained from various books, that psychology can be a valuable ally not only to the law, but also to the prisoner and to society at large. There are quite a number of types of cases that regularly come up in police-courts which are better dealt with by psychology than by punishment. To take one example, many petty thefts by young people have no motive that seems adequate Psychological study shows that many of these are the result of the impulses of self-expression being persistently frustrated, until they seek an outlet in theft, either by way of a symbolic revenge upon society, or to gratify some thwarted desire for vanity or possession. Such cases can often be put right by adjustment in home life or living conditions, while imprisonment would only have aggravated them. Various sex offences can also best be dealt with in this sort of way.

In general, courts should have professional psychologists attached to them. They alone are qualified by their training to shed light on the deeper sources of the motives of accused persons. In most courts at present, either psychology is not called in at all, or it is called in in the form of expert witnesses on the two sides. But psychology is too important for this: like law, it should be in the service of justice alone.

The relation of psychology to justice is rather like that of medicine to education: when universal education was started in this country, it was soon found that defective health and nutrition interfered with education, and the school medical service was started as an integral part of the educational system, with admirable results. So with justice—you cannot be sure of being just if you are dealing with the psychologically sick or deficient: you need a law psychology service as an integral part of the legal system.

However, even if there were a psychologist in every court in the country, they could not do much without a reform in our penal system. For much of this, too, is based on a pre-scientific attitude of mind. Much of the law, like many of the ideas of the general public, is still conceived in terms of punishment, instead of the ultimate good of society or of the offender. And in this attitude society, as I pointed out in discussing the idea of conflict introduced by Freud, is really giving outlet to its repressed impulses to violence and its hidden fears, and is using the man or woman who happens to have transgressed the law as a scapegoat on which these may be vented with gusto and a good conscience. Our own unconscious sense of guilt is eased by punishment inflicted on the law-breaker.

There is undoubtedly room for punishment in the treatment of law-breakers; but there is also room—and, indeed, crying need—for what we have not got at all—a system of detention aimed at cure, in which the offender is looked on as diseased, instead of, or at least as well as, criminal or immoral, and psychotherapy, among other agencies, is used to cure him and send him back as a fit member of society. This would in

the long run effect a great saving of money, as well as of other less tangible things like human aspirations and human happiness. In this respect, by the way, Soviet Russia is a good deal in advance of our own country.

Besides our legal system, our whole attitude to sex could do with an overhaul in the light of psychological knowledge. But that will prove more difficult; for, since the sex impulse is not only intensely powerful, but, under present conditions, usually the most forcibly repressed, the unconscious forces at work are most powerful, the unconscious resistances are more difficult to overcome, the tendency to be unforgiving about other people's offences in the field stronger.

Here we have arrived in the field of social psychology. I had something to say about this in the previous chapter, in relation to the causes of war. One could, indeed, write a whole series of chapters on the subject, for every social problem has its psychological side; but, as my space is not unlimited, I shall have to confine myself to one or two special points. For instance, I would like to stress the need for more psychology in the art and business of government. Government is inevitably becoming more of a technical affair, concerned with increasingly complicated problems, which are changing all the time. Both the complication and the speed of change are much greater than in any previous period of history. In the circumstances, government cannot be successful unless it either has great power and is very autocratic, or unless it gets the understanding and interest of the population it is governing. Even the autocratic governments of to-day depend a great deal on propaganda and mass-suggestion, though these may be

rather crude—witness Soviet Russia or Nazi Germany. It is vital for them to have propaganda which is psychologically along the right lines. Germany has recognized this by establishing a Ministry of Press and Propaganda.

In this country we are still carrying on with more democratic methods. Hence it is even more important to ensure that the mass of the people should be interested in what the government is after, and understand its problems and its policies sufficiently to feel real enthusiasm for its main aims. Already we have sporadic examples to show that this truth is recognized—such as the campaign of enlightenment that has recently been carried out on the subject of slums, or the excellent work that was done in explaining the national advantages of last year's Conversion Loan. But the principle wants to be recognized in every department. Crude propaganda is not good enough: people like to be taken into the confidence of the powers that be. To accomplish this properly, a new art is needed—propaganda in the good sense, information and persuasion, publicity that is not mere advertising: the Government and all its departments ought to realize that its relations with the public are a very important branch of its activities. Perhaps *public relations* is the best phrase. Already the Post Office has made a beginning by appointing a Public Relations Officer, but there should be a whole Department of Public Relations, which, of course, would have to base its activities on applied psychology. But I must not launch out into speculations about the future. I would only ask my readers to think what could be achieved in regard to public health, the popular understanding of financial proposals, cam-

paigns against noise or against smoke, campaigns for town-planning or for the preservation of the countryside, and a thousand and one other matters of national importance.

But even this would be only a beginning. I wonder if my readers will agree with me when I say that the greatest single trouble of this country to-day, outside the pressing economic sphere, is the lack of outlets for collective enthusiasm, collective beliefs, collective idealism?—a lack which has become especially acute with the decay of orthodox religion as a vital popular force? Perhaps I should say the lack of certain kinds of good outlets: there are plenty of outlets good in their way, but insufficient in others, like sport, and other outlets which are more embracing but bad, like class-spirit or narrow nationalist patriotism. Human nature, as at present organized, feels the lack of such outlets, and in their absence makes them for itself, often in unsatisfactory form—witness the crudeness and violence mixed up with the idealism and the enthusiasm in German Fascism. It would take too long to discuss here what sort of outlets and aims are desirable, and how they could be brought into being. But whatever the answer, it is clear that both technical advice from psychological science, and the scientific spirit in the shape of careful planning, will be needed to avoid the dangers that arise from idealisms kindled for a wrong or unsatisfactory end, or allowed to stamp out variety and freedom of thought by their very enthusiasm.

Collective enthusiasms and beliefs are to the community very much what private enthusiasms and beliefs are to the individual. I am sure that sweeping

statement can have a lot of holes picked in it; but it is roughly true—and brings us face to face with the idea that the community is in a real sense an organism, with laws of its own, capable of scientific study like any other phenomenon. That study results in the science of sociology—still very much in its infancy, but capable of enormous development. I heard Sir Josiah Stamp, at the British Association last year, make a strong appeal for guiding as many as possible of the best scientific brains of the young generation away from the sciences of matter—physics and chemistry—and into the sciences of life—biology, psychology, and sociology. He was quite right: it is in the fields with which these deal that the danger-point lies now. We have got a great deal of control—quite enough to get on with for the time being—over lifeless nature: we have practically no control over human nature, and over the monsters we have unconsciously created, or at least allowed to grow up unchecked, in the shape of economic systems, unintelligent moralities, nationalist sovereign states, mass ignorance, and mass hysteria.

Let me try in conclusion to indicate quite briefly some of the more important conclusions to which we are led by a scientific study of man and society.

To take but two examples. One is the sweeping conclusion, devastating to many timid minds, that no absolute standards exist, in morality, truth, art, or anything else: they all are relative. This is most simply seen in the field of morality, where the idea of what is right and wrong does actually, and must inevitably, change with change in the form and outlook of society.

We have mistaken the abstract for the absolute.

There is an abstract idea of Good—but it has no content: the content of the idea, and therefore of morality, is and must always be relative. In other words, we have to build the system of morality which is the best possible in the present condition of the world, just as we have to organize the best possible system of education or public health. It is no good trying to shift our responsibility on to God, or our ancestors, or a philosophical Absolute: "Heaven helps those who help themselves" is as true here as in any other department of life.

The other point I would like to emphasize is that we are influenced by our social environment to an extent that most of us do not realize, and would perhaps be horrified at if we did realize it. Even if the influence takes the form of a reaction against the existing order, instead of acquiescence in it, it is none the less real and compelling. That has two lessons—in the first place, one aim of education should be to teach people to discount the unconscious prejudices that their social environments impress upon them. The other is that the social and economic system is, in large measure at least, subject to deliberate and scientific control—though it will be as tough a job to bring it under control as it was to bring Nature under control; and that we can only expect to have people leading full, rich lives (which is, I suspect, the right approach to the eternal problem of happiness) if we bring into existence the right kind of social and economic system for the community. The quality of human life is determined by the social organization, much as the quality of a commercial product is determined by the machinery and processes used to make it.

"This is all very utopian," I can imagine many of my readers saying. It may be; but, meanwhile, our lives *are* being determined by the social machinery around us, and if we do not try for a scientific solution of the problem, we shall have an unscientific one forced upon us, in the shape of Fascism, or Revolution, or just chaos and drift.

However, I would like to end with a perfectly tangible suggestion for the applying of scientific methods to social problems. I spoke earlier of the enormous degree of innate differences between different people There is absolutely no reason to suppose that, if we wanted to, we could not utilize this fact to improve the general quality of the human race, its physique and intelligence, its general capacity for living, as strikingly as we have been able to improve the breeds of our domestic animals—and for what that means you have only got to think of a fine modern carthorse and racehorse, as against the little wild horse from Asia, a good herd of Jersey cows against a flock of wild cattle, a faithful watchdog against a wolf. Of course, no one suggests that you could apply the same methods to human beings as to farm animals, nor that the aim in view would be similar: for one thing, variety, not uniformity, must obviously be a major aim for man. But the long-range improvement of the human race by eugenics is obviously destined, once we have dealt with the more immediate problems of social organization, to be a major outlet for human altruism and human hope. When you think of the possibilities involved, it is rather absurd to find that the only body concerning itself with the problem in this country is a private one, the Eugenics Society, with comparatively

few members, mostly laymen in science. Yet, in a way, that is all you can expect Such a society can help to rouse public interest; and at the moment that is the chief thing which it can do, for as yet we have not the knowledge to embark on large practical measures

But why should not the Government provide the knowledge—through the Census, which already provides extremely valuable knowledge about the numbers of people in the country, their occupations, religious beliefs, birth-rates, death-rates, and so forth? It would be quite simple to extend this to gain much of the knowledge needed as a possible basis for eugenics. For instance, the census of 1911 gave us most valuable statistics for the birth-rate in different economic classes of the population—showing, for example, that unskilled labour had a net rate of increase about double that of the professional classes. In later censuses, this information has not been forthcoming—on the ground of expense! The Census could easily become an instrument for a real national stock-taking. If trained biologists and psychologists were called in to help with it, we could obtain a picture of the biological qualities of our national stock of human beings—which, after all, is in the long run the one asset that really matters—and the directions and trends along which it was changing.

Facts are the food of science: if we are going to be scientific about human nature and human society, instead of just trusting to blind social and economic forces (and see what a mess that blind trust has led us into!), let us begin by insisting on a proper supply of facts as grist to the scientific mill.

Last of all I would like to mention one fact which ought to be remedied. That is, that there are less than fifty psychologists attached to our universities, and probably, excluding psychological doctors, less than a hundred professional psychologists in the country. And as for social science, I doubt if Britain supports a couple of dozen people devoting themselves primarily and professionally to the subject. The other day I attended the dinner given to celebrate the twenty-first anniversary of the founding of the Biochemical Society, and learnt, to my surprise, that it numbers over eight hundred members, although it represents a very young and rather specialized branch of chemical science. The contrast is striking, and does, I think, justify me in stating, as the main conclusion of this chapter, that the scientific structure of this country is lop-sided, and that the sciences dealing with man are lamentably neglected.

CHAPTER XI

PURE SCIENCE

DISCUSSION WITH PROFESSOR P. M. S. BLACKETT

J. H. Well, Blackett, I am glad to have you here. There are quite a number of points on which I feel my views could do with a little clearing-up, and a discussion like this helps in the clearing-up process.

P. B. As a matter of fact, Huxley, I was rather hoping that you would clarify some of my ideas. I suppose you have seen a more varied assortment of scientific work than anyone else in existence—at least, you have seen it in a shorter time.

J. H. Yes, I suppose that is true—I *have* seen a pretty good sample, from physics to psychology, from the purest mathematics to the most applied agriculture, from breeding insects to designing aeroplanes, from university laboratories to iron-works, from amateurs pottering about with field-glasses to huge Government research stations. The impressions I have got are so varied that sometimes it is rather hard to sort them out and see just what they mean.

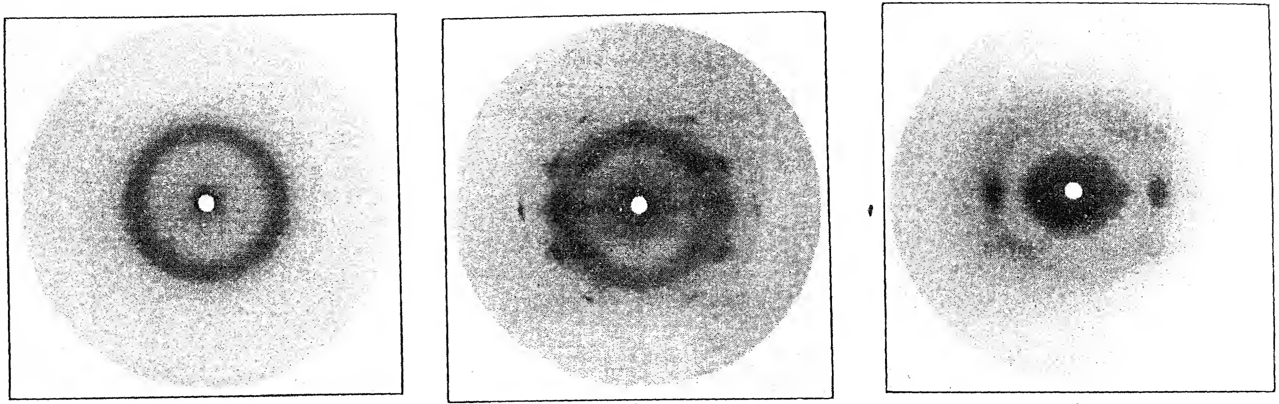
P B. Yes, I should think so But now, out of all these impressions, what are the chief points which have emerged that you think this discussion of ours could help to clear up? I gather it is to deal mainly with pure science.

J. H. Well, I thought there were a number of

topics we might try to cover. First of all, whether there is any real line between pure and applied science. Then whether discoveries in pure science are not influenced by practical considerations, and, indeed, sometimes do not arise directly out of applied research. And to what extent pure science is limited by mere technique. Then there is the question of why people go in for research as a career, and their own attitude to their work. Also the reason for the greater prestige of pure as against applied science. I also hope to deal with the possibilities open to the amateur scientist. And, finally, there is the whole question of science in education and the problem of getting a scientific background into the general consciousness.

P. B. That is a long list! So let us begin right away. Now that you have seen a lot of both pure and applied science going on, do you find the line between them easier or harder to draw?

J. H. On the whole I have realised that it is harder to draw the line even than I thought it at first. And in one respect I have corrected my previous ideas. I used to imagine that important new discoveries always started as pure science, and gradually filtered down into practice, *via* applied science. Of course, that *is* the usual way. Sir William Bragg, in his introductory chapter, has given a number of good examples from the work of Faraday and other scientists who have held posts at the Royal Institution. And this is the view you will find in practically all the books on the subject. As they are mostly written by pure scientists, or by popular writers who get their ideas from pure scientists, I suppose it is natural that they should emphasize this view. But I have been much



A B C

X-ray photographs: (A), of an unstretched rubber band; (B), of the same rubber band stretched to seven times its original length: the difference in the pattern shows that the stretching has altered the intimate structure of the rubber. (C), an X-ray photograph of human hair, stretched and set in steam at twice its original length. (*See* pp. 80, 205.)

From the *Journal of the Society of Dyers and Colourists*, June 1933.
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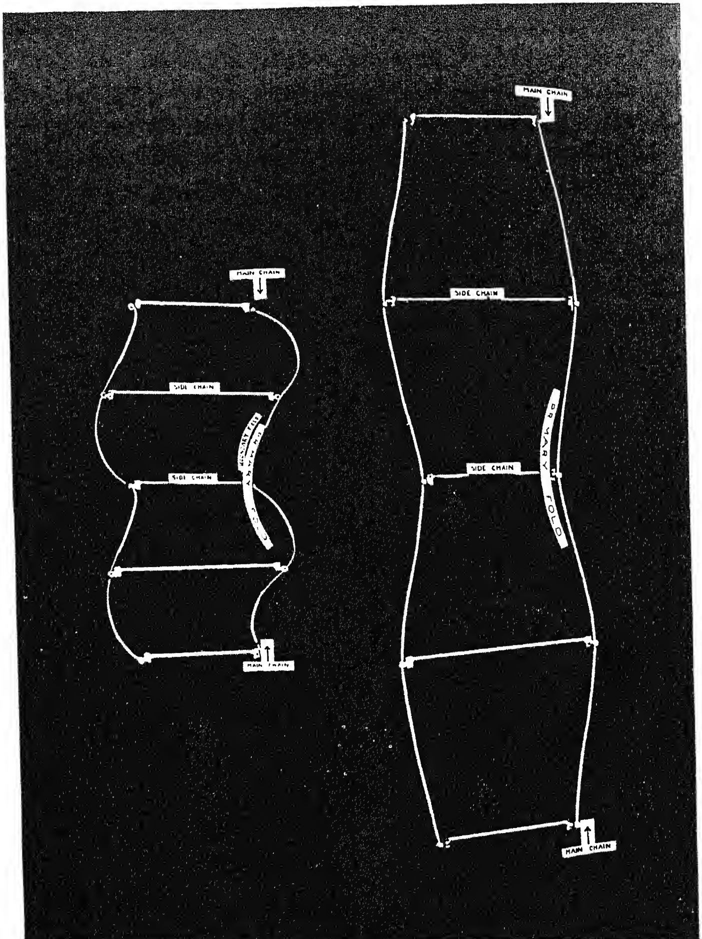

Models to illustrate the different form of the wool molecule in unstretched wool fibres (left) and stretched wool fibres (right) as determined by X-ray analysis supplemented by chemical tests. Only a small section of the very long " molecular ladder " is shown. (*See* pp. 80, 206.)

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interested to find that things do not always happen that way.

P B. Give me an example.

J. H. Well, perhaps the best case I saw concerns the use of X-ray analysis of the fine structure of solid materials. It is so good because it shows you both the opposed tendencies at work—first the flow from pure to applied, and then back again from applied to pure. It all began with very pure laboratory research—but, of course, you, as a physicist, know more about that than I do

P. B. You mean Laue showing that X-rays when passed through crystals were diffracted so as to give what is called interference patterns, and then the Braggs showing that from the particular patterns you could discover exactly how the atoms were arranged in the different crystals?

J. H. Yes. And, of course, quite soon this was taken up as a practical thing, to give information about the internal constitution of materials when other methods were no good—when microscopes will not magnify enough, for instance, or there is not enough material for chemical analysis. All over the place I found X-rays being used in practice: in steel works, in all sorts of ways—for instance, to detect the invisible changes due to cold rolling and tell you just when to stop; in the electrical industry, for making electrodes for high-temperature discharge tubes; in the glass industry, for finding out the causes of opalescence in glass; in engineering, for dealing with certain kinds of scale in boilers; in the paint industry for determining the size of grain in paints, and therefore their consistency.

P. B. Well, so far things have been going according to the usual rule, have they not—from the pure scientist in his laboratory out into industrial practice ?

J. H Yes, but now the reverse process comes in. Up at Leeds, in the Textile Department of the University, I had a talk with Dr Astbury. He had been working with Bragg, and had shown that with the aid of X-rays you could get new information about the intimate structure not only of ordinary crystals, but also of products of living organisms, such as plant and animal fibres As a result, he was asked to go to Leeds to study wool from the practical textile point of view. He told me that he had some misgivings as to whether this work was not going to be much less interesting than the pure scientific studies with which he had been busy up till then. The sequel, rather amusingly, was just the reverse: the interest of his work has steadily increased, until he now finds himself concerned with some of the most fundamental and exciting problems of biology. It turned out that the wool fibre is a particularly favourable object for studying the intimate structure of protein molecules. As proteins are made of the most complicated molecules known, with hundreds or even thousands of atoms in them, this was, in any case, interesting. With regard to wool protein in particular, Astbury was able to prove that the actual molecules were elastic, and could be pulled out like a concertina, or perhaps more like a spring, and that it was this fact which gives wool its extraordinary springiness! This, in conjunction with research by a chemical colleague in the department, is leading to all sorts of improvements in the wool industry—for instance, to

much-improved methods of pre-shrinkage for woollen fabrics

But it is leading much further afield, for protein molecules are the most essential kinds of molecules in all living matter, and new discoveries about any of them means some fresh light on all. So this work on the wool fibre, undertaken for severely practical ends, is turning out to be of importance for all branches of biology, up to the most pure. For instance, the work seems likely to throw light on the very puzzling things that happen in immunity—as when the injection of a protein into the blood causes the animal or man to produce something which will destroy that particular protein, but no other, if it is injected again later. Most fundamental, it is giving us much new evidence on the actual chemical structure of the protein molecule—how it is built up of long chains linked together ladder-wise by rungs of special atoms at intervals. So here quite definitely the current of discovery, after first flowing from pure to applied, has reversed its direction, and gone from applied to pure.

P. B. Is not the history of how the Second Law of Thermodynamics was discovered an obvious example of the same tendency—that is, of how a very important piece of pure and abstract theory arose out of a very practical technical problem?

J. H I had not realized that.

P. B. Yes. The Second Law of Thermodynamics arose from the attempt to make steam-engines more efficient. The use of steam power was already wide-spread, when Carnot, while seeking to understand in detail how steam-engines worked, was led to a first formulation, though still an imperfect one, of what is

now called "The Second Law of Thermodynamics" To-day, this second law of thermodynamics appears one of the most far-reaching of all physical laws. Did not Eddington say once that against the Second Law there is no possible appeal? So the most abstract and general of laws arose from the study of that most concrete of objects, the steam-engine.

J. H. Do you mean that you think that the Industrial Revolution *caused* the discovery of the laws of thermodynamics?

P. B In a sense, yes At least, it was clearly no accident that thermodynamics was not discovered in the late seventeenth century, when there were no steam-engines, and was in the early nineteenth, when there were steam-engines.

J. H. Of course, it is always difficult to say which is the cause of two things which are found to happen together—for instance, nationalism and wars, or even the hen and the egg. But it is, I think, quite clear, not to say trite, that there is often a close relation between practical problems and advances in pure science. Is it not a fact that the needs of improving efficiency of radio-transmission have led to very fundamental discoveries about the upper atmosphere?

P. B. Yes. The work of Appleton and others on the highly conducting upper layers of the atmosphere has given us absolutely new knowledge about our own planet, and opened up a fascinating field of pure research. And the work arose directly out of the discovery that it is possible to send wireless messages round the earth.

J. H. Well, Blackett, I want to ask you a question. You used to work at the Cavendish Laboratory at

Cambridge. I went there recently, and was naturally much excited about all the work on the structure of the atom going on there. But do you think that that is at all influenced by what is going on in the practical world outside?

P B. Yes, I think it is to a great extent dependent on what goes on outside. But that is not quite the same relation that we have been discussing. I do not mean that the problems studied have necessarily any relation with any industrial or social needs; but the technical methods used are largely dependent on industrial technique.

J. H. But what about the famous "sealing-wax-and-string" methods? I thought, from what I have heard said, that all the best experiments were done with the simplest apparatus.

P. B. Well, perhaps that was so once. But it is not now. Why, Lord Rutherford's own experiments require an apparatus of extreme complexity: innumerable valves and rows of thyratrons flashing, relays clicking, and so on It looks rather like a cross between the advertisement lights in Piccadilly and the transmitting-station of a modern battleship. No, the sealing-wax-and-string era is, perhaps unfortunately, over. In its place modern physics uses all the technical assistance it can get. In fact, it may be said that the limits of knowledge at any time are set by the technical means available. I believe that the reasons for the rapidity of advance of modern physics is not the superiority of the physicists of to-day, or even their number, but that it is to a considerable extent due to the technical aids made available by industry.

J. H. You mean the wireless valves you have just

been speaking of? And then there are photographic plates and the cinema. I suppose all these are an essential part of much physical apparatus to-day.

P. B. Yes. Then the recent work on the disintegration of atoms by high-speed particles has owed an enormous amount to the electrical industry, through which high-tension transformers, condensers, and so on have become readily available. In fact, the industrial development of high-tension power transmission, culminating in this country in the "grid," has made new experiments possible in the laboratory.

J. H. You mean that physics is limited much more by the existing limitations of the materials and instruments which it must use, than by the limitation of pure thinking, or any lack of bright ideas?

P. B. Certainly. The discovery of new materials makes new advances possible. Often a possible experiment is thought of, but has to wait a generation for the necessary technique to make it possible to carry it out.

J. H. I suppose the same sort of thing would be true in astronomy with telescopes, would it not?

P. B. Yes, absolutely. With the naked eye we can see only a tiny portion of the universe. The invention of the telescope at once made it possible to see a bigger fraction. But ever since Galileo's first telescope in the seventeenth century, the size of the fraction has been steadily increased by technical progress. At the moment the biggest telescope in the world is a one-hundred-inch reflector, but a two-hundred-inch reflector is just being made, which will multiply what we can now see sixteen-fold. The 4
difficulties in making and grinding a two-hundred-

inch mirror are enormous, but they are merely technical.

J. H. I see So the progress of this branch of astronomy is entirely dependent on the technique of glass-making and glass-working. In general, I take it, you mean that applied science, in the form of technique in the control of materials, is a real limiting factor in the progress of scientific theory—pure knowledge, so called. How the scholastic type of philosopher in the Middle Ages would have disliked this idea, and, as a matter of fact, still dislikes it in our own time! It is a slap in the face for the intellectualist, the believer in absolute knowledge, the highbrow in general.

But there is still another possible way in which pure science, it is suggested, can be influenced by practice. That, too, Levy touched on in our opening discussion—I mean the idea that the general direction which pure science takes is not, as most scientists like to assert, just determined by the free play of the human intellect, but by the social and economic needs of the place and period. Do you believe that?

P. B. On the whole, yes. Consider Newton's achievements, for instance. He did not himself think of all the problems he so brilliantly solved. The problems were there, waiting to be solved—it was essential both for industry and navigation that they should be solved. A more accurate theory of mechanics was essential for the development of many machines in industrial use, and also for improvement of guns. Then the development of astronomy was required for the new developments going on in ocean navigation. For instance, the problem of determining a ship's

longitude at sea was urgent. This demanded either an accurate chronometer or a knowledge of the motion of the moon. So important was the problem that the Government of the day offered prizes for both these things, thus effectively, and quite impartially, stimulating both pure and applied science. There is no doubt that Newton was stimulated by the general background of technical problems waiting to be solved, to do his wonderful theoretical work

J. H. You mean the influence is there, but is rather general? I think there are examples of that sort in my line of country too. For instance, there is all the work going on in connection with the big museums of the world, collecting, naming, and classifying the thousands of kinds of plants and animals. This sounds rather useless, but it is really essential for such practical problems as controlling insect pests or insect-borne diseases. Indeed, it is not too much to say that one essential, both for prosperous agriculture and for good health—the latter especially in the tropics—is this accurate systematic work that goes on in museums; and that the realization of this fact has led to the great development of this kind of work and institution in the last hundred years

I think that there are two separate things involved. There are impulses in human nature and there are social and economic influences. After all, for centuries there have been people with a strong bent for natural history who have collected and classified animals and plants. But they have been few and sporadic. It is only recently that the big museums have come into existence for doing the collecting and classifying systematically with a large

staff, on a large scale. And big museums cost money, and that would not have been forthcoming if it had not been for the pressure of practical needs. Is it not money which counts? Through the control exerted by money, the practical needs of the time encourage the growth of one branch of science, while another only just manages to exist because no money is forthcoming.

P. B. You mean that the man who pays the piper calls the tune, and there must be some strong practical inducement to make him pay? That certainly is exemplified by the fact that at the moment the Government does a very large part of the paying in one way or another—to an extent which most people perhaps do not realize—and it would not do that unless it felt it was getting its money's worth.

J. H. Yes. Of course most of the money put up by the Government for research goes for the very practical needs of war, industry, and agriculture.

P. B. And also remember that the Government, through the D.S.I R. and other scholarship schemes, supports directly a large number of young scientific workers during their first few years of research. I myself was enabled to start research after the war by a Government grant The number of scientists who get a start in this way runs into hundreds a year.

J. H. But of course you also get a great deal of pretty pure research done by private firms, who must obviously be actuated by the profit motive.

P. B. Yes, and sometimes they help to finance Universities—for instance, the chemical laboratory in Cambridge just after the war received a big endowment from the oil industry.

J. H. *Apropos* of all this, in my last chapter I was lamenting the fact that scientific research in this country was badly lop-sided, with not nearly enough being done in the biological, and especially the human, sciences. I suppose you would agree this was due to the stimulus given to research and teaching in physics and chemistry by the huge development of the industries based on these sciences, like the electrical and chemical industries and engineering?

P. B. Certainly—up to a point. But is there not also another set of influences at work, of a more emotional nature? Orthodox religion has not been very favourable to biological advance, has it?

J. H. That is true enough. It really is almost funny to-day to read the insults that were hurled at Darwin and my grandfather on the evolution question—though it was serious enough at the time. But of course the process still goes on. Orthodox morality to-day is not very favourable to modern psychology, and I know a case where the fact that a young biologist had done research on problems connected with birth control stood in the way of his advancement.

But I would like to ask you another question. What about research which is nominally done for practical ends, but as a matter of fact is actually useless? For instance, the breeding of new wheats which can be grown in new regions, like semi-deserts or the arctic, just when there is no profit in wheat from the ordinary wheat areas? That sort of work is still going on.

P. B. Well, I suppose that is because the work was started when it looked as if it would be useful, and, once started, it carried on with its own momentum,

so to speak. I am sure there is a momentum of this sort in all scientific research, both pure and applied.

J. H. Yes, I think that is fair enough. Once a scientific problem has been properly stated, it more or less inevitably works itself out. I suppose that is true with your work in atomic physics As soon as the facts of radioactivity made it clear that the atom was not the ultimate unit of matter, but had a structure of its own, research was bound to go on and clear up the problem of just what that structure was

P. B. Perfectly true . On the other hand, the *rate* at which a problem gets worked out depends on the number and quality of the research workers engaged on it, and the facilities at their disposal; and that is largely determined by the money available. The momentum is always there, but it is helped or checked by practical considerations

J. H. And, of course, pure research gets more and more complicated and expensive all the time, so that those practical considerations come to have more and more of an influence. But we must not spend all our time on this question. I want to get your views on another point—about the individual research worker in pure science. Why does anyone in particular go in for science as a career?

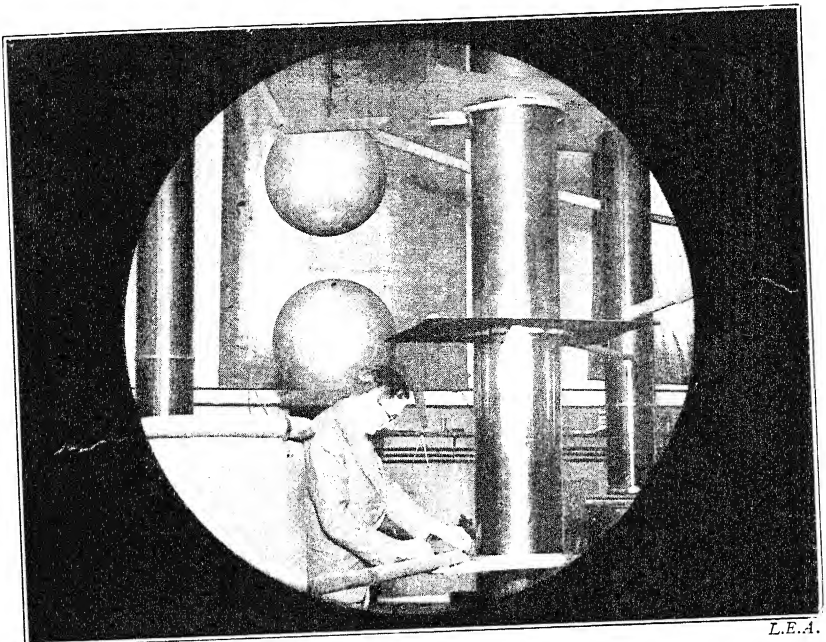
P B Well, in my case it was largely that I liked doing things with my hands, and had a strong mechanical bent.

J. H. I suppose there are plenty of people in physical and chemical laboratories who get started that way. But I think there are other quite different bents which also bring other types in. For instance, there is the natural history bent. Many boys, often with

poor mechanical ability, have a passion for Nature. When this is combined with a strong collecting instinct, it may produce the systematic zoologist or botanist; when not so combined it is likely to give the world the general biologist or geologist. Charles Darwin had a very strong collecting instinct, combined with a deep love of Nature. Then there is the more philosophic bent, which, if not too philosophic, but combined with an interest in concrete objects, gives you what we may call the scientific scholar, who is primarily interested in bringing intellectual order into his branch of science. William Bateson had this, rather curiously combined with the collecting instinct. Sir Arthur Eddington has it combined with intense mathematical ability. And finally, there is the social bent, that impulse to do something useful. This has sent many men into professions like medicine or the Church: so long as scientific work provides opportunities of obvious usefulness, it will send some men into science.

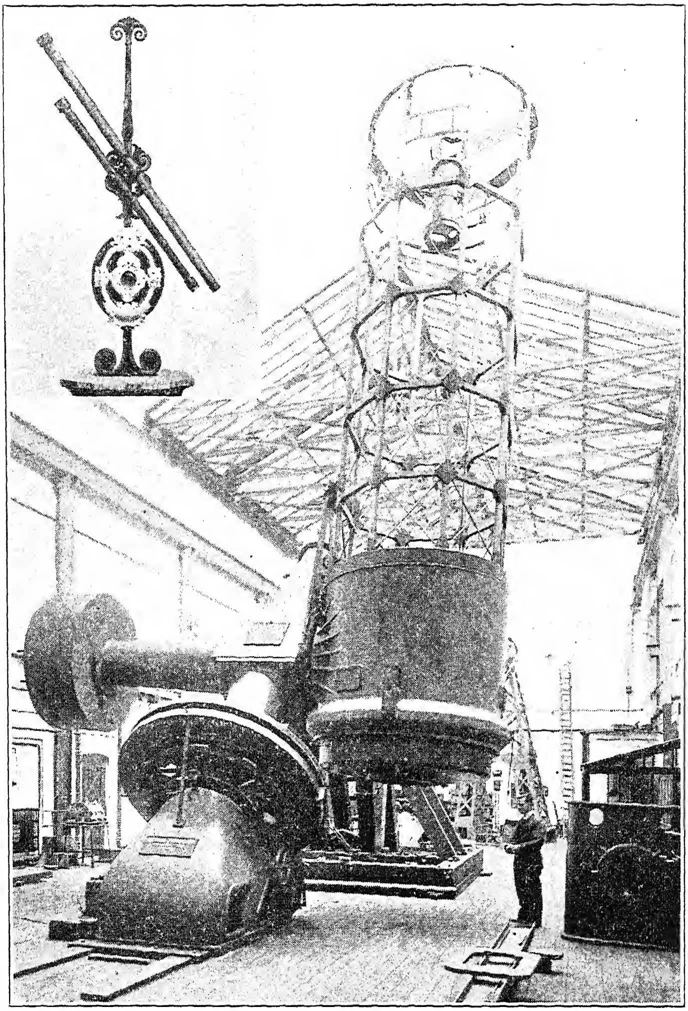
P. B. But that will not explain why there are so many more scientists to-day than formerly.

J. H. No. That, I take it, is a question of outlets and social atmosphere. It is obvious that men and women with these same various bents must have existed all through history, but that they could not have become scientists in the days before there was any science. In the Middle Ages, the mechanically-minded had very few outlets—that bent hardly got a chance, any more than it did in pre-war Russia. There were few outlets, too, for the collecting bent—save perhaps a few odd professions like that of the herbalist. The nature-lover had to satisfy himself with hunting or the life of a farmer. The scholar's bent pushed



L.E.A.

Fundamental research may demand elaborate apparatus. Dr. Walton in the Cavendish Laboratory, Cambridge, with his high-tension atom-splitting apparatus. (*See* p. 210.)



Technical skill increases man's knowledge of the universe. Galileo's telescope (inset) contrasted with a modern telescope (a 74-inch reflector for the University of Toronto, built at Newcastle-on-Tyne). (*See* p. 210.)

By courtesy of "Nature" (for 74″ reflector). *The Galileo Telescope from "The Depths of the Universe," by G. E. Hale (Scribner).*

men into theology or philosophy, the social bent into becoming a parson or a friar.

P. B. Yes. And even if we compare to-day with the Victorian era, conditions have changed a great deal. The clerical profession no longer has either the social or the intellectual attractions it used to possess. The war has influenced a great many people against a naval or military career. Business is not paying so well; politics has not the prestige it once had. So it comes about that a number of young men who a couple of generations back would not have thought twice about entering one of the traditional professions, are to-day taking up science

J. H. I think that is true. And so long as there are scientific posts to fill, this state of affairs, though perhaps unpleasant for the country at large, is good for science.

P. B. Yes, certainly. But then there is the question of the scientist's own attitude towards his work. Did you, for instance, get an impression during your tour that any marked difference of attitude exists between those working in pure research laboratories and those in technical laboratories?

J. H. Well, I think that in the best industrial laboratories, at any rate, the keenness and intellectual interest in the work were just as marked as in, say, the Cavendish Laboratory. Still, I think there is usually a greater attraction in pure research, connected with the intellectual excitement of finding out general laws, and also a greater prestige attached to it.

P. B. On the other hand, it is a fact that the actual activity which occupies nine-tenths of the time of an experimental physicist is nearly the same, whether

the work is pure or applied. Actually, I am inclined to think that the greater prestige in many quarters of pure as opposed to applied research is partly due to the pleasanter conditions under which it is often carried out. For instance, the Universities offer such a pleasant mode of life, where one is one's own master of how and when one shall work, that some of the attraction of the conditions under which work is done gets attributed to the work itself.

J. H. But, after all, I think it is reasonable that pure research should enjoy its present great prestige—though it is certainly going a bit far when a scientist goes out of his way to claim that his work is completely useless.

P. B. Yes. I have heard that boast too. I am not sure I have not made it myself. There certainly are elements of snobbery in that claim. That society should pay one to amuse oneself at an entirely useless occupation is gratifying to one's self-satisfaction. Whereas formerly social prestige was attached to not working at all, now it is sometimes attached to doing something useless.

J. H. Well, there is another side to it. Society always likes to have its prophets—its medicine-men, if you like—to tell it about the deep mysteries of the universe; and science, in the persons of some scientists at least, is tending to become a substitute for theology in this field, isn't it?

P. B. Yes, I think it is clear that the general public likes to hear about science, or rather about some aspects of science.

J. H. And also a good many people like to do amateur scientific work for themselves.

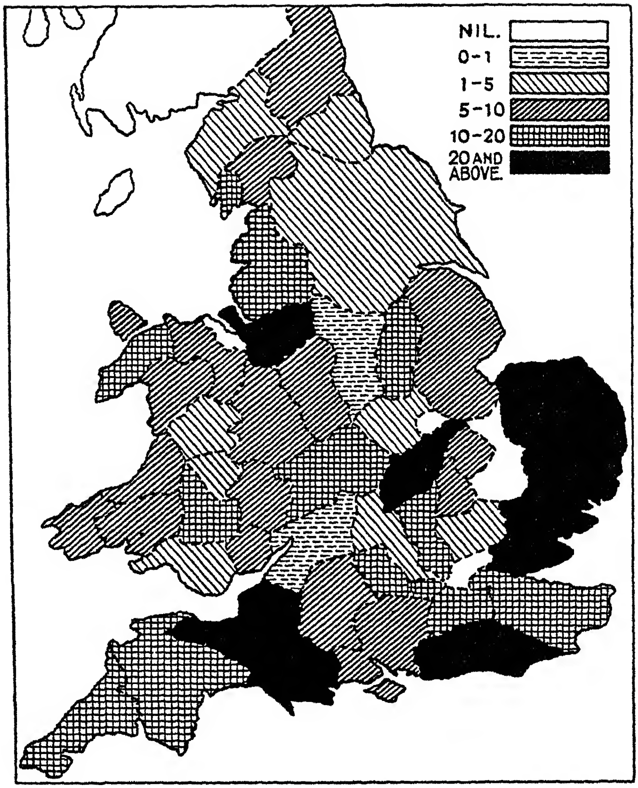
P. B. Well, I don't think that is possible in modern physics.

J. H. That is a pity—but it is possible in various other fields. For instance, the Meteorological Office gets reports from observers all over the country as to the dates of flowering and fruiting of various wild plants. Then there was a scheme launched about twenty years ago by the British Ornithological Union to study the migration of birds, which secured valuable results. That also needed the collaboration of observers all over the country, and I remember as a boy the interest it added to my bird-watching At the moment a rather ambitious scheme has just been launched to start a National Institute of Field Ornithology at Oxford, which should act as headquarters for all the bird-watchers in the country, to plan out schemes in which they could take part, to give information as to the most interesting lines of work for the amateur to take up, the best methods to be adopted, and so on.[1]

Then amateur astronomers carry out a good deal of useful observation. Again, there are regional surveys to be undertaken, in which botanists, entomologists, geographers, and all sorts of others interested in field science can profitably co-operate. These can best be carried out under the auspices of local scientific societies, of which there are a good many doing valuable work in this country.

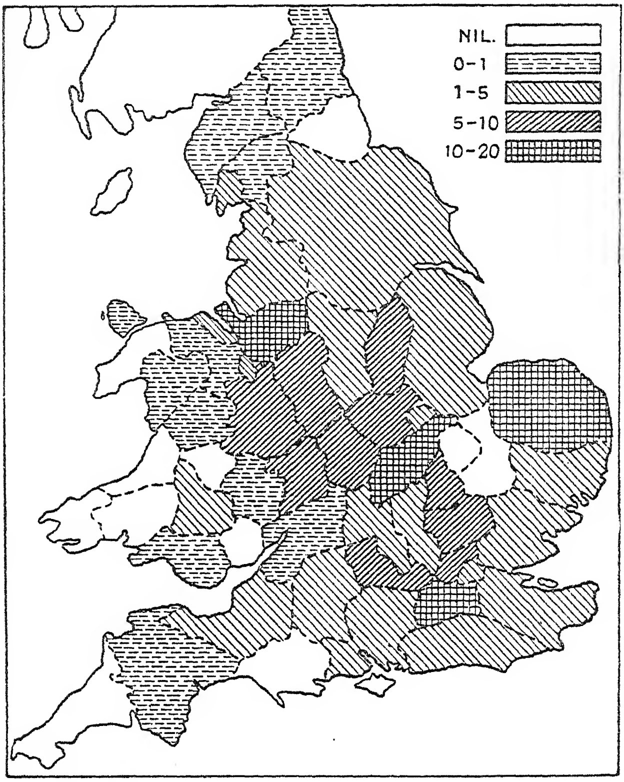
P. B. And, of course, the amateur radio fans have done very useful work—it was they, I believe, who first started experimenting with short-wave transmission, and so indirectly stimulated the researches which led

[1] Anyone interested in this scheme can obtain particulars from Dr. W. B. Alexander, The Museum, Oxford.



Results of co-operation by amateur scientists A map showing the density of population of the common heron in England and Wales. The different shadings show the number of breeding pairs per 100,000 acres. The research was organized through the ornithological journal, *British Birds*. (*See* p. 219)

By permission of E. M. Nicholson and the Editor of "Discovery."



Another piece of co-operative amateur research. The map shows the density of population of a water-bird, the crested grebe. The shading indicates the number of breeding pairs per 100,000 acres; the same areas are used as for the heron (p. 220). The resemblances to and differences from the map for the heron are interesting. (*See* p. 219.)

By permission of E. M. Nicholson and the Editor of "Discovery."

to the recent extension of our knowledge about the upper layers of the atmosphere of our own planet, that you mentioned earlier.

J. H. Yes. And my general point is that the amateur scientist has always flourished in this country, and with a little organization—such as the B.B.C. itself has on occasion helped to provide—he can continue to be really useful to science, while at the same time having an interesting hobby for himself.

P. B. But that can only cover a small part of the population.

J. H. Oh, certainly! But by proper education you can interest a great number of people in science.

P. B. Why do you want to?

J. H. Well, take my own subject, biology. I am keen on more biology as a recognized part of general education. This is important from the point of view of health, and will also encourage a sensible attitude to life, as opposed to one based merely on tradition or prejudice. I have rather a quarrel with you physicists and chemists for pinching so much of the science curriculum in schools!

P. B. But would a better scientific education make so much difference, after all?

J. H. Not much, perhaps—so long, at any rate, as people imbibe a whole set of contrary ideas along with their science. At the moment, our civilization is very scientific in its attitude to some problems, like engineering or aviation, but highly unscientific in regard to others, like education or politics. One ought not to mix one's general attitudes, any more than one ought to mix one's drinks.

But something could be done if the powers that be

really believed in scientific method, and if the mass of the people really believed that science could help to put the world right, then scientists would get a better chance to help us out of our troubles.

P. B. But just how could science be of more help in the direction of affairs?

J. H. Well, to start with, by the collection of statistics on social matters. After all, science must begin with the facts

P. B. Well, that will not take you very far. I should imagine that there are already innumerable blue books with admirable collections of facts that have never been acted on. For instance, the League of Nations' report on the Armament Industry, published soon after the war.

J. H. Oh, but that is only the first step, though a very necessary one. My point is that you could get a general outlook in the country which would be scientific all round, just as you may have a nationalist outlook, or a religious outlook, or a socialist outlook.

P B. No, there I disagree! As a matter of scientific observation I find that my scientific colleagues, between them, represent all the possible outlooks you have mentioned. And, of course, this is inevitable. For once one gets into the field of action, everyone becomes a politician, however much he may try to be scientific.

J. H. I agree that at the moment scientists have their personal and their class prejudices, like anyone else. I was really thinking of a slow process tending towards a more uniformly scientific outlook on social problems. However, we are getting into rather deep water, are we not? We can't really go into the

question now. But I shall make a point of taking it up with Levy in my final discussion with him.

P. B. Well, don't be too optimistic. I am afraid that if society thinks that the scientist is going to be its saviour, it will find him a broken reed.

J. H. And that would be bad for science as well as for society. All right, I promise I will not be too optimistic; but I still feel that a scientific attitude to social problems is better than an unscientific one, and that we could do something to get it realized.

CHAPTER XII

SCIENCE AND INTERNATIONAL NEEDS

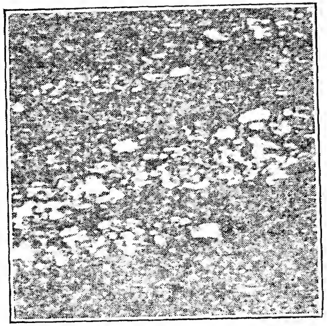
SO far, I have been speaking about the scientific research going on here which is directed to the needs of this country. In this chapter I want to say something of its wider aspects—imperial and international.

The British Empire is the biggest, the most scattered, and the most heterogeneous political association there has ever been—or that there is ever likely to be until the World State arrives. It contains over a fifth of the land areas of the globe, and nearly a quarter of its population. It embraces one whole continent and bits of all the five others. It includes entirely uninhabited territories in the Antarctic, and also some of the world's most densely populated regions. Among its inhabitants are Eskimos who have never seen a tree or a horse, African savages who kill lions with spears, Dyak head-hunters who have never seen ice or snow, Australian black-fellows living a life not unlike that of our prehistoric ancestors a hundred thousand years ago. In it live the great majority of the Hindus; it includes more pagans than Christians, more brown and black people than white. It comprises self-governing dominions, crown colonies, self-governing colonies, protectorates, native states, mandates, and spheres of influence. What is science doing towards the needs of this extraordinary agglomeration?

In the first place, of course, most of the separate units have their own scientific organization. India is one of the few countries to boast a Biological Survey—though this has suffered a good deal in the crisis. The dominions have all their own universities, agricultural research stations, and so on. When I was in Africa four years ago, I saw something of the excellent work being done by the research workers in such subjects as medicine, agriculture, forestry, geology, veterinary science in our various East African colonies

This is as it should be; for however general scientific problems may be, they arise in different forms in different conditions, and can only be worked out locally. Let me give just one example. Soil science, thanks largely to the Russians and to the work of English scientists at Rothamsted, has during the present century reached a high development. But tropical soils provide a special problem. Owing to the heat and the different conditions of tropical rainfall and plant growth, their formation and nature are different from those of temperate regions. So it is essential to study them on the spot. In East Africa this is being undertaken by the fine research station at Amani, which I visited, perched high up in the tropical rain-forests of the Tanganyika hills. The Germans started it, and after the war we enlarged it to serve the needs of all the East African territories. The information it is getting on African soils will be invaluable for local agriculture, and could not have been obtained from research at home.

But essential though local research is, centralized work and co-ordination are also necessary, and a great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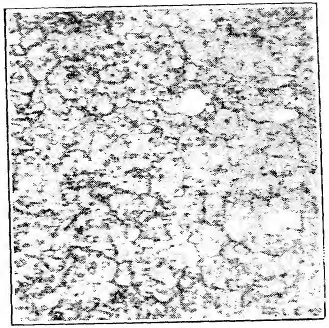
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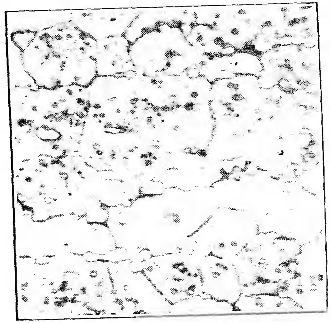
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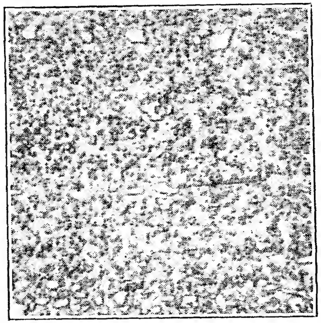
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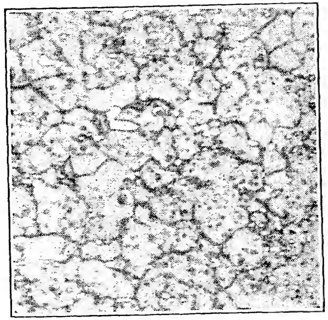
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Scientific advance in one field makes for progress in other fields: how the microscope helps in the steel industry. Photographs taken at a magnification of about 500 diameters of the polished and etched surface of high-speed steel treated in various ways.

A, high-speed steel after being softened (annealed) for machinery. The white patches are carbide patches. Satisfactory reheating treatment for hardening should cause the disappearance of most but not all of these particles.

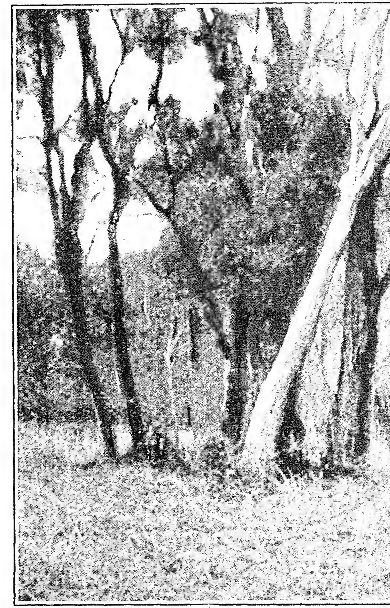
B, C, D, E, portions of the same steel after quenching (hardening) in oil following reheating to 1150°, 1250°, 1300°, and 1375° C., respectively. The microscope tells the expert that B and C are not hard enough, while the structure of D and E is satisfactory.

F, heated to an excessive temperature (1400–1450° C.) and air-cooled. The coarse structure shows that the material has been spoiled. The only method of dealing with this would be remelting. (*See* p. 204.)

From *The Application of Science to the Steel Industry*. *By courtesy of the author, Dr. W. H. Hatfield.*


(a)


(b)


(c)

(*a*) Agents of biological control. Caterpillars of a species of moth (*Cactoblastis cactorum*) specially introduced from South America into Australia to feed on prickly pear. These, together with certain cochineal insects, have proved very effective in checking the pest.

(*b*) A plant pest. The prickly pear, introduced into Australia as a hedge plant, spread in some parts of the continent to form an impenetrable scrub like this.

(*c*) The effects of biological control. Three and a half years after the large-scale liberation of various insects which fed on prickly pear, the dense scrub of the pest has been eaten down and killed. (*See* p. 229.)

From *The Biological Control of Prickly Pear in Australia*, by A. P. Dodd.

By courtesy of the Commonwealth of Australia Council for Scientific and Industrial Research.

deal has been done to provide these, especially in the years since the war. One very important method of co-ordination is that of the Imperial Agricultural Bureaus, established after the Imperial Conference in 1927. These were attached to laboratories where especially good work was going on in the particular subjects concerned. Their function is to collect and analyse all the information in their particular field, and to make it available for the Empire at large, either by publishing bulletins and summaries, or by replying directly to queries. So, to go back to soil again, the Bureau for soil science is attached to Rothamsted. The usefulness of the work at Amani on tropical soils is not confined to East Africa, for it is all collated by the Bureau at home, studied in relation to the general principles of soil science, and made available to other tropical dependencies

I came across several of these Bureaus during my tour of this country. The one for animal breeding is attached to the Animal Breeding Research Department at Edinburgh, the one for animal nutrition to the Rowett Institute at Aberdeen, the one for pasture and grassland to Stapledon's place at Aberystwyth. They are not all in Britain, however; in accordance with the principle that they should be attached to the institution where the most important research on the subject was in progress, the one concerning veterinary science, for instance, was put at Ondesterpoort, in the Union of South Africa.

There is no doubt that these co-ordinating and distributing centres are performing a very useful function. And, as their publications circulate everywhere, they are useful to the world at large as well

as to the Empire, and indeed in some cases they are almost in the position of world centres

The same sort of thing, in addition to much actual research work, is done by two other bodies, the Imperial Institute of Entomology, which works in close co-operation with the Natural History Museum at South Kensington, and that of Mycology, which works in liaison with the Royal Botanic Gardens at Kew. Mycology is an unfamiliar word—it means fungus science, and the Institute concerns itself with all the moulds and rusts and other fungus pests of trees and crops.

Entomology, of course, is the study of insects, and insects are the most serious enemies of man in the world—much more serious than any of the larger animals. Think of all the work going on in connection with the Institute of Entomology and the insect room of the Museum at South Kensington, some men spending their lives collecting insects of every possible kind from all the corners of the earth, and other men spending their lives describing, naming, and classifying them. (This, by the way, is a pretty big job, as half a million or so different kinds of insects are known already, and hundreds of new kinds are discovered every year.) Most people, I suppose, if they ever give it a thought, would say it was a very useless and unpractical sort of job. Yet its practical importance is really very great, because if any animal or plant is useful or harmful, the first essential, in taking practical steps about it, is to be sure you know what you are dealing with. It is not much use knowing vaguely that mosquitoes carry malaria. As a matter of fact, some do and some do not; and of those that do, some breed

in certain well-defined kinds of situations, and others in others: to get rid of malaria, you must, as a first step, be able to identify and name the different kinds Or again, one particular beetle may be very destructive to crops, while its first cousin is quite harmless. If you want to deal with the pest by what is called biological control—keeping its numbers down by means of introducing parasites—you will find that you must have very accurate knowledge of the different species of parasites, because one may only attack the harmless beetle, while a close relative, which perhaps at first sight looks just the same, is very effective against the pest.

The Imperial Institute of Entomology identifies over one hundred thousand specimens of insects every year, including a number of species new to science. (It is, by the way, interesting to know that the number of wholly new species described is steadily mounting year by year, so little has man yet explored the biology of this planet.) More than half the resources of the Institute go towards the publication of a periodical which gives abstracts of all scientific papers dealing with the activities of every kind of insect pest throughout the world.

To illustrate the importance of systematic work, I may mention an example from the sphere of Mycology The citrus-fruit plantations of West Australia were suffering seriously from a fungus pest. This was taken to be the same as a similar fungus which had been doing damage in Florida, and the control measures that had worked well in Florida were tried, but with no effect. Then the Imperial Institute of Mycology looked into the matter,

and found that the two fungi were really quite distinct, and had quite different life-histories, so that wholly different control measures were needed in Australia.

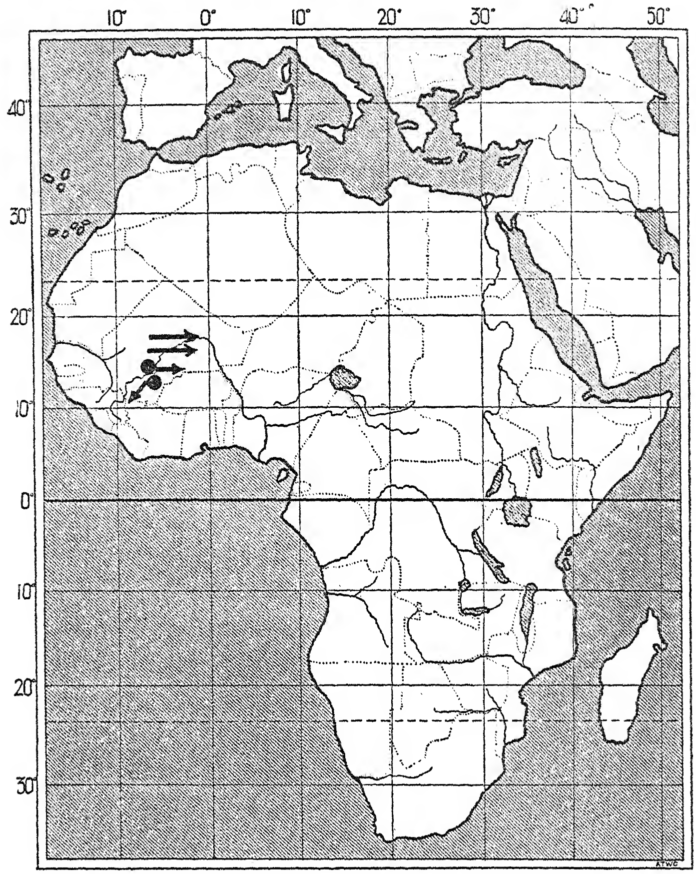
One of the most fascinating scientific institutions in existence is the field laboratory of the Institute of Entomology, out at Farnham Royal. This has been nicknamed the " Parasite Zoo," for its function is to supply parasites in bulk to all parts of the Empire. The parasites are parasites of insect pests; they are themselves insects, which lay their eggs in the grubs or eggs of the pests and devour them from the inside. In some cases this method has been a spectacular success. For instance, the valuable coconut crop of Fiji was in serious danger of destruction from a little moth which somehow got introduced into the islands towards the end of last century. Three entomologists were set the job of finding a parasite for it. At the suggestion of the Imperial Institute of Entomology, they looked in Malaya, and there found what they wanted. By chartering a special steamer, living parasites were brought to Fiji, bred there in bulk, and liberated; and within four years the moth had become so rare as no longer to be of any importance as a pest.

At Farnham Royal, entomologists are engaged on the search for the right kinds of parasite, the study of all their little habits, the best methods of rearing and transporting them in bulk. They are now busy trying to find a parasite for a sawfly which attacks Canadian wheat. That such problems are of very practical importance is shown by the fact that this particular species of insect did over two million pounds worth of damage in one year in Manitoba alone!

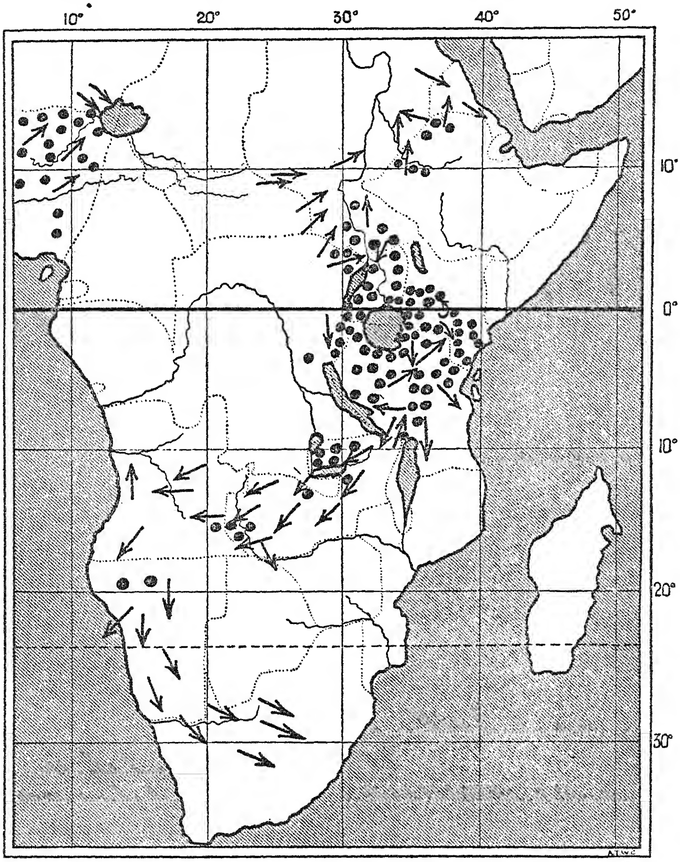
Other extremely important work on insects is done

by Committees of the Economic Advisory Council. One instance is the research on that fearful scourge of African men and African cattle, the tsetse fly. This work, thanks largely to the success of Swynnerton's long-continued practical experimentation in Tanganyika, is now entering on a new and more hopeful phase. Equally important is the work of the Locust Committee. At the end of the war, the Imperial Institute of Entomology secured the services of Uvarov, a Russian scientist who had discovered the unexpected but fundamental fact that all true locusts existed in two quite different forms, a solitary form which lives like any other grasshopper, and a swarming form which possesses the instinct to migrate in huge hordes. Besides their habits, the two differ also in their colour and a number of other points. Since then much of the research has been directed to finding where the solitary form has its main home, from which the hordes of swarmers will set out when they are produced; and to discovering what causes one form to change into the other. If you can find the main home, you may be able to prevent disaster by destroying the locusts there when they are not swarming. The Committee receives reports from all over Africa as to the presence and movements of locusts, and the mapping of this information is now beginning to narrow down the field in which to look for the main homes of the three different species of African locusts.

Meanwhile, another line of attack is being tried. Experiment showed that locusts in flight were killed very quickly by finely-powdered sodium arsenite. After many trials, it has been found possible to manufacture this in the shape of a dust fine enough to be



International co-operation in anti-locust research. All the records of locusts sent in from every part of Africa are plotted on monthly maps, from which general maps showing the breeding places (dots) and the migrating swarms (arrows) are compiled. In this map is shown the Migratory Locust situation in 1928, when the beginning of the present outbreak was recorded: the first swarms arose close to the bend of the Niger, and soon developed a tendency to spread, mainly eastwards. In the following generations the swarms extended right across the continent, then turned south, and by the ninth generation in 1932 (see map, p. 233) the whole of East Africa was overrun by swarms. Their migration then took a general south-westward direction and many swarms reached South



Africa, where they arrived at the wrong season and were unable to breed owing to the dry and cold weather.

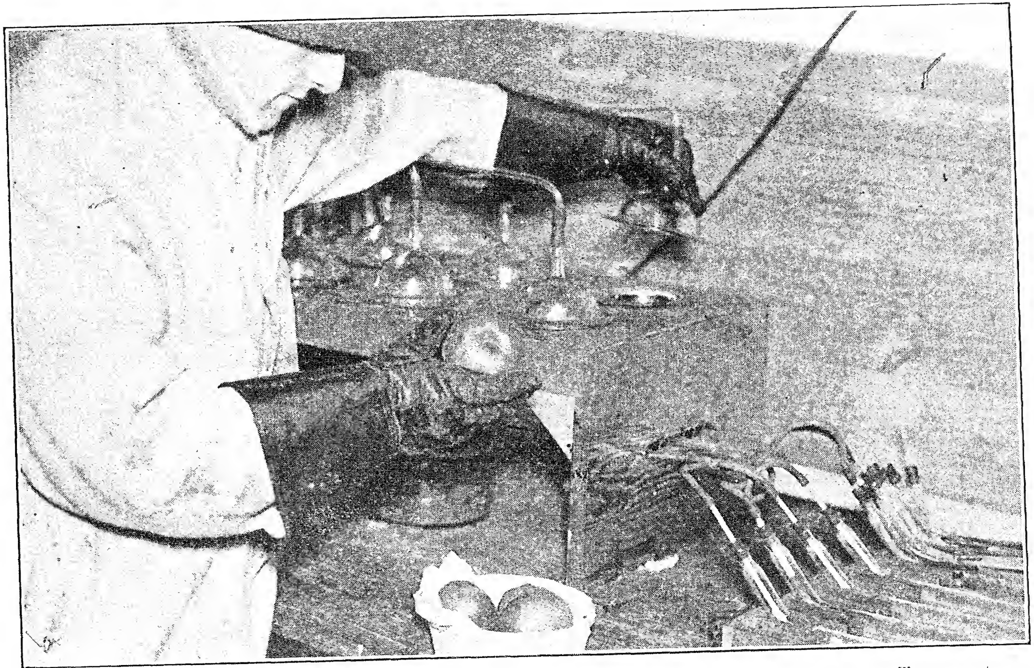
The map on p. 232 indicates where the outbreak originally arose by a transformation of the solitary phase into the swarming one (see text). Maps like that on this page are used to study the laws regulating the migrations so as to be able to forecast locust invasions. (*See* p. 231.)

(Redrawn after the Reports of the Economic Advisory Council's Committee on Locust Control.)

discharged into the air as a cloud; and now an aviator has gone out with an Imperial Airways machine to Northern Rhodesia to try the effect of flying over a swarm of migrating locusts and discharging this poison dust right into them. If it is as successful as is hoped, it will be much the best method for checking the ravages of locusts once they have started on their migratory career.

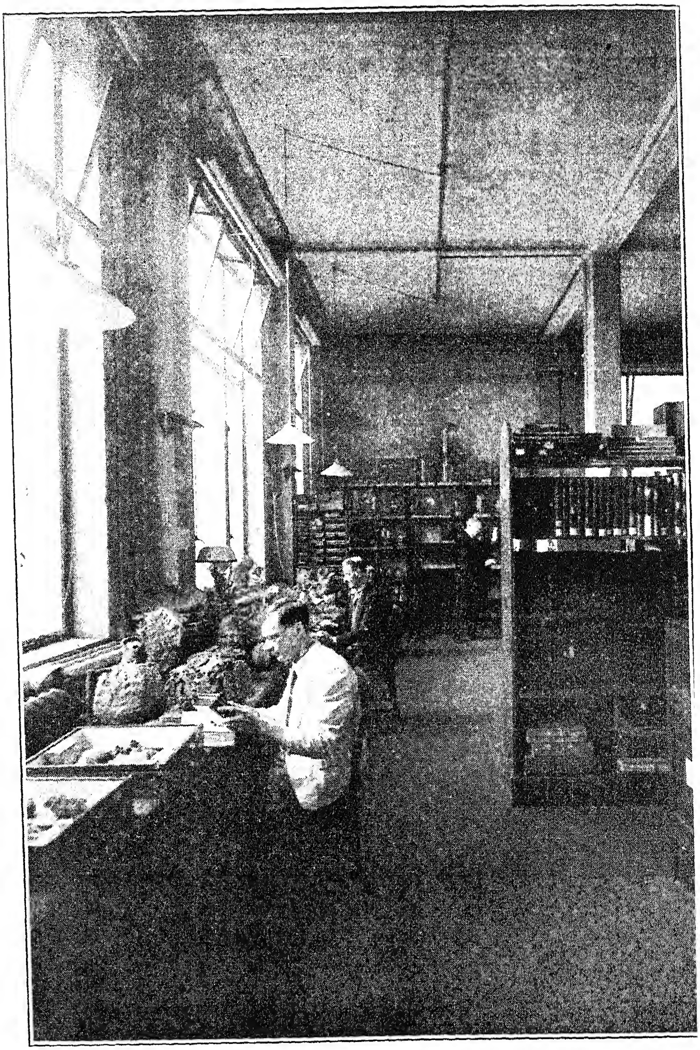
Now I come to another point. The work at the "Parasite Zoo" was largely financed by the Empire Marketing Board, which, as most people know, came to an end last year. It has now been in part taken over by an organization which deals with the Imperial Bureaus, and is supported by all parts of the Empire; but owing to its type of organization, this is constantly having to refer decisions back to the Governments concerned, and it has only been financed for a year at a time. This lack of security is very bad for a scientific institution, both because it prevents any proper continuity of policy, which is essential for science with its long-range vision, and because it leaves the scientists engaged on the work in a very insecure and unsettling position, with unsettling effects on the existing staff and increased difficulties in recruiting new personnel of high standard.

The ordinary public knew of the Empire Marketing Board chiefly by its posters and its propaganda campaigns; but behind the scenes it was engaged on a really big programme of research. To give only a few examples of its research activities, it was giving substantial help to the valuable work of the D.S.I.R. on cold storage, which has made it possible to transport apples and other fruits across the ocean and to store home fruit for long periods without appreciable loss,



Science and cold storage. A scientist in arctic kit in one of the cold rooms at the Low Temperature Research Station, Cambridge, testing the rate at which apples breathe at low temperatures. (*See* p. 235.)

By courtesy of the "Daily Express."



Museum research. A corner of one of the rooms of the insect department of the Natural History Museum at South Kensington. (*See* pp. 212, 228.)

By permission of the Trustees of the British Museum.

and is leading to marked improvement in cold-storage methods for meat and fish. It has financed work by a zoologist on the curious cycles of alternating abundance and scarcity which are found in many animals and birds. This is proving to be of importance to home agriculture in regard to periodic plagues of field mice; to the fur industry in regard to prophesying the fat and lean years for fur trapping; to medicine in forecasting the times of abundance of wild rodents which carry human plague; to the sportsman in understanding the causes of periodic scarcity of game-birds; and so on. Then it helped in a very interesting investigation on the possibilities of "road-trains," with special chassis and a large number of wheels, capable of operating in new countries over the roughest roads: this, if successful, may prove to be the solution of the goods transport problem in many parts of Africa, India, and Australia. To scientists in this country whose work concerned problems of imperial scope, it gave grants to travel and see the men and the problems on the spot—a most important means of securing added efficiency.

In general, it has often helped to finance research for which it might have been difficult to get funds through the ordinary channel, because it overlapped into several fields, or concerned several different governments, or was of rather an unusual or adventurous nature. Its untimely end is a real blow to scientific research on a co-operative imperial basis. It is a curious commentary on the phase of nationalism through which the world is passing, that this work, so hopefully launched and so well carried out on a basis of co-operation between the different parts of

the Empire, should have split largely on the rock of nationalism on the part of certain of the Dominions, who, to put it bluntly, wanted their own show rather than co-operate with a central body, however good, which had its headquarters in London—though of course the economy campaign must bear its share of the blame

To show what difficulties are being brought about by the expiry of the Board, I may mention the case of Kew. Most people know Kew for its lovely gardens; but it is also the centre of botanical research for the Empire. On any question of identifying a plant, you call in Kew. Most of the staff are engaged on work in the Herbarium, which houses an enormous collection of plant specimens from all over the world, duly named and classified. The Herbarium has eight scientific workers of its own; but, in addition, the Empire Marketing Board was paying the salaries of seven other scientists to get on with this important work, also of several technical assistants, and of an economic botanist, who also has been busy on a most important job—nothing less than a complete descriptive catalogue of all the plants grown as crops for profit anywhere within the Empire. And of course the problem now is, what is to become of all these men and all the work they have begun? Should not the authorities in this country take over the responsibility?

That sort of systematic work is just as important for higher plants as it is for fungi or for insects. This is notably so for many useful timber trees and fibre plants, which may look very much like some other less useful species. Sometimes you have to take extremely fine points into consideration. For instance,

there are two varieties of camphor plant. One yields camphor oil when distilled, but the other is much more desirable, because it yields the solid camphor which is wanted commercially. Yet the two cannot be distinguished to look at

Or again, a species of St John's-wort, that pretty yellow wildflower, got accidentally introduced into Australia, spread like wildfire, and turned into a real pest. It was identified as the common British St. John's-wort, and certain insect enemies of this plant were introduced into Australia to attack it. But they had no effect. Then Kew looked into the matter carefully, and found it was really the continental variety, which is extremely like the English variety in appearance, but is attacked by different insects !

But it is not only such systematic work with which Kew is concerned. It was responsible for bringing the cinchona tree, from the bark of which quinine is made, from Peru to India, and so helping in the campaign against malaria; for getting the Brazilian rubber plant from its native home and distributing it over the Empire; for spreading the tung-oil plant of China, which yields such good paint and varnish, all over the semi-tropics; and the chalmoogra plant, which yields the best specific against leprosy, from its Asiatic home into Africa and the West Indies, where it is badly needed. Often the process is carried out in steps, the plants being grown for a spell in one of the greenhouses in Kew before they are sent out to their new homes.

There are many other fields in which empire needs are dictating the course of research. One very important one is forestry. Think of the teak of Burma, the

square miles of pine forests in Canada being used up every year for timber and for newsprint; the amazing variety of trees in the tropical forests of India, Africa, Guiana. The imperial centre for forestry is attached to Oxford University, and at Princes Risborough there is a Forest Products Station of imperial scope under the D S.I.R.

Then there is medicine All sorts of diseases happily unknown in this country are prevalent in the tropics. Apart from all the research on tropical medicine that goes on in India and the colonies, a good deal is carried out in this country to cater for the needs of sailors and others who have come back after contracting such diseases abroad. So we find the study of them chiefly in our two greatest seaport towns, London and Liverpool.

I wish I had space to treat of the Seamen's Hospital down by the docks, and the work of the School of Tropical Medicine, now combined with the Ross Institute for Malaria, in Bloomsbury, but I must pass on.

There is also an imperial side to broadcasting. Empire radio is destined to be an important link between Englishmen all over the globe, and that depends a great deal on the progress of research on short-wave transmission, which is being actively carried on by the G.P.O., the commercial companies, and the B.B.C.

Radio links up with the human element; and this is perhaps in the long run the most important of all fields for science that is planned on the Empire scale.

One of the greatest difficulties in the way of a scattered heterogeneous empire like ours is to effect mutual understanding between groups differing in race, colour,

tradition, and level of civilization. The wireless and the cinema, both products of applied science, are likely to be the most important agencies in this respect, if properly used. I remember talking in Kenya with the head of the Medical Department, and hearing of the extraordinary success he had had with a home-made film in persuading tribal natives to co-operate in a campaign for ridding their area of hookworm and other diseases; and recently comes news of a large experiment in India, in which villages are to be provided with communal wireless sets.

Still more important is scientific research on the human beings themselves. We are astonishingly ignorant in many ways about our Empire. There are no reliable vital statistics over most of Africa. I tried when I was there to get some information as to infant mortality: all that I could discover was that it must be terribly high—perhaps six to twelve times as high as in England, so that sometimes half the babies born would die in the first year of life; but accurate figures were lacking on this and on the equally important question of the average length of life of African natives.

Things are pretty bad, too, as regards research on health. Some years ago the Medical Research Council and the Empire Marketing Board had an investigation made of the physique of two neighbouring Kenya tribes, the Masai and the Kikuyu, in relation to their diet. The result was very striking. The Masai are famous for their good physique and bravery—they are among the tribes who kill lions with spears. The Kikuyu are of smaller stature and of much poorer physique. This is specially true of the men; the women, though small, are renowned for their power

of carrying heavy weights. I myself saw a woman carrying a load of firewood which I could only just lift off the ground with my two hands, she was carrying it for several miles

Now, the Masai live entirely on animal food—almost exclusively the blood and milk of their cattle. The Kikuyu live mainly on a vegetable diet, which is not satisfactory as regards its food-values, and, what is more, the men, owing to tribal traditions, have a poorer diet than their women-folk. There is, it appears, no doubt that the addition of a moderate amount of high-quality protein, in the form of meat, to the Kikuyus' diet would raise their physique and energy quite considerably. Nor do the Masai escape the penalties of one-sidedness: they appear to suffer a good deal from diseases of rheumatic type, which in all probability could be much reduced if they took to a better-balanced mixed diet.

I also found when I was out there that the belief still lingered among some white employers of black labour that the black man needed only a few handfuls of maize-meal to keep him in good trim. This is, as a matter of fact, a complete fallacy: a black man has the same general physiology as a white man; and many complaints about "lazy niggers" and the like owe their existence entirely to the short-sighted policy of the white employers who want to get a great deal in labour for next to nothing in the shape of food, and provide a cheap diet on which no human being, white or black, can help being listless and without energy.

Although there has been much improvement of late years in the diet provided for native labour, especially by big concerns like mines, it still remains

true that improper and inadequate diet, whether due to their own or their white employers' fault, is one great cause of backwardness among the native inhabitants of Africa—and doubtless of other primitive parts of the Empire Considering what far-reaching effects their increased energy would have—greater efficiency in their own agriculture and in work for white employers, greater ambition and greater intelligence, greater needs and greater purchasing power—it is almost ludicrous that this preliminary investigation of the two Kenya tribes has not been followed up by a full survey on an imperial scale.

However, it must be admitted that scientific research, however well it may bring out the facts, is not always acted upon This is all too clear in another branch of medicine—that which deals with parasitic disease. To go back to East Africa, because I happen to have been there myself, I know that the medical authorities agree that it is very unlikely that there are *any* adult natives who are not suffering from some drain on their health due to parasitic infection—whether roundworms, or the horrible hookworm which sucks blood from the walls of your intestine and energy from your whole system, or the microscopic malaria parasite which infects your blood and, even if it does not give rise to acute fever, keeps you chronically below your full level of vitality, or the numerous other tropical diseases caused by living invaders. In Western European countries, these parasitic enemies of man have been brought under adequate control, and sometimes entirely stamped out. There is no ultimate reason why they should not be also in Africa or India. If this were done, and at the same time diet were

corrected, the whole character of the black and brown peoples of the Empire would change, and a new level of life could be opened to them. Here indeed is a field for science and its applications.

Another vast field for research is in anthropology—the study of human customs and beliefs and social organization. Some very serious mistakes have been made in the past even by the most well-meaning of missionaries and administrators, simply because they did not understand the ideas of the people with whom they had to deal To take only one example, land among African tribes is not owned outright by individuals, but by a clan or family group, regarded as existing in the past and the future as well as in the present. Individuals have only temporary rights. Usually the chiefs have certain more or less feudal rights as well. The white man comes along with his ideas, and may convert a chief's feudal privilege into outright ownership, or get at loggerheads with a whole clan when he imagined he was only dealing with an individual.

Some of the most difficult problems arise with natives who are no longer living their immemorial tribal lives, but are living in contact with the white man's system. For these, there is grave danger of falling between two stools, and acquiring the less desirable qualities both of white and of native life. Here a new kind of anthropology is needed—not the very pure kind which was always looking out, quite naturally, for the most primitive and the most untouched tribes, but an applied anthropology, halfway to sociology, to study the effect of mixture of cultures with a view to guidance and control. Of late years, a beginning has been made with such work, largely under the influence of Professor

Malinowski of the London School of Economics, and of the International Institute of African Languages and Cultures; but the problem is acute, and much remains to be done. So it is good news that a scheme is now in being in this country whereby in the near future a broad comparative survey is to be made of Africa. This African Research Survey will deal with the problems of our African Empire under four heads—that of economics, of administration, of anthropology and sociology, and of natural science. By this means it is hoped many gaps and defects in co-ordination will become apparent and the way be opened for a more scientific policy.

At any rate, this is a truly scientific approach to the problem of the large backward areas of the world, and perhaps out of it there will grow some provision for an institution on a more permanent basis which could continue to make provision for that ever-pressing need, scientific study, and could act as an advisory centre for African affairs.

This survey will also take notice of what is being done in the African possessions of other nations. Here, it will be seen, an international aspect comes in. The same, by the way, was true for the much more specific example of locust research. In this field the Italians and the French are co-operating with us by sending in reports from their territories to the Locust Committee in England, which collates the information for the benefit of all parties concerned; and international conferences on the subject are held periodically.

As a matter of fact, the shrinkage of the world due to improved communications is making international co-operation in science and research (as in many other

fields !) even more pressing than in old days. Let me just recall the fact that the League of Nations has a Health Section, and that this is co-operating with other interested bodies to investigate the possibility of spreading diseases, such as yellow fever, by aeroplane, and to lay down regulations to minimize the danger. It has also undertaken important special investigations, such as that into the best methods of getting rid of malaria in Europe, and it has further done valuable work in regard to biological and medical standardization.

Perhaps you are surprised to see that word in a biological context, but I can assure you that standardization is just as important for applied biology—in medicine, veterinary science, agriculture, and public health, for instance—as it is for applied physics and chemistry in industry. I spoke in an earlier chapter of the results achieved by insulin in diabetes. But they could not be achieved without an extremely exact dosage.

Diabetes is essentially an inability of the tissues to utilize the sugar circulating in the blood, which is the main source of fuel for their vital energies. The way insulin helps in diabetes is by making it possible for the tissues to do this. If you do not give enough insulin, the tissues do not take up enough sugar, and the diabetic symptoms are not removed. If you give too much, the tissues take up so much sugar that enough is not left in the blood, and all sorts of serious consequences may ensue. So before insulin could be safely prescribed, it was absolutely necessary to have it standardized. It is a tribute to the accuracy with which this was done that it can be, and is, now so widely used in practice without any ill effects.

The first standardization was done under the auspices of our own Medical Research Council, just after the war. It speedily became clear that international standardization too was desirable, and it was soon arranged that this work should be supervised by the Health Organization of the League of Nations. The actual standardization work is farmed out to different countries. This country, as a matter of fact, has been entrusted with more of this work than any other, and it is impressive to see, in the National Institute for Medical Research at Hampstead, a case containing the actual biological standards of about twenty important biological preparations, kept there, as the standard yard and pound are kept at the Board of Trade.

They include the standards of certain antitoxins, like that for diphtheria; of certain drugs which need very careful dosage, like salvarsan and the other arsenicals used for sleeping sickness; of various hormones such as insulin; and of the different vitamins, so important for diet and general health as well as for special diseases like rickets.

International standardization, of course, also exists on the physical side. For instance, there is the Comité International des Poids et Mesures, with which the National Physical Laboratory is collaborating, among other things, in a scheme for determining a new international standard of length in terms of that most fundamental natural property, the wave-length of a particular kind of light.

Another interesting example is the International Tin Research and Development Council, which grew out of the work started by the British Non-Ferrous Metals

Research Association in this country. It is an excellent example of how a really good programme of research cannot help being essentially international in its activities, and tends to attract international support. Though the headquarters of the Council is in London, this is simply for convenience, and the work is truly world-wide There is, by the way, a further interest in this case. Britain is exceptionally well situated to provide headquarters and staff for many similar kinds of research. It is a small and centralized country, with world-wide connections, and a high professional and scientific standard. This sort of export—the export of brain-work—could become an important item in our economy if we took steps to encourage it.

International co-operation is also going on in research on meteorology in Greenland and other parts of the Arctic, with a view to establishing the short air route between Europe and America—and, indeed, in many other fields.

Of course, the progress of pure science has always been to a very large extent international. I do not suppose most of my readers realize the enormous scale on which the interchange of scientific knowledge is going on all the time between different countries. To start with, scientific journals circulate all over the world. Any good scientific library contains English, American, German, French, Dutch, Italian, and Russian periodicals, and those of many other countries besides; and often maybe a German periodical will contain articles by American or Italian scientists, and so on.

In biology alone, some 60,000 separate scientific communications are published every year, not to

mention over 1,000 books; so that one of the most pressing needs of science is the provision of a really good abstracting and summarizing service—journals which give brief but reliable abstracts of all papers published, and others which provide well-written critical resumés of recent work in particular fields. Much has been done in this direction, but there is still great room for improvement. In a properly organized world-state, this duty would be carried out on a large scale by some well-equipped central organization; but at the moment this and other aspects of a "world-brain" are still very rudimentary.

Then there is interchange by means of travel—either by a tour through the research institutes of another country, or by exchange professorships, or by spending several months working in the laboratory of an authority on some particular scientific subject. This is a most fertile method, and has been much aided by the policy of various bodies, such as the Rockefeller Foundation, which provide so many research fellowships for able young workers to hold abroad.

Then, of course, there is interchange of knowledge by means of international congresses and meetings. In almost every branch of science these are held at intervals of a few years, in different countries by rotation. Personally, I remember vividly the interest of meeting physiologists from all over the world at the International Physiological Congress in Edinburgh, of going to the International Congress on Heredity in Berlin, and talking for the first time with a number of Russian research workers whom I had previously known only by their published papers, of meeting German and French and Dutch ornithologists at the

International Ornithological Congress at Amsterdam, of going to Geneva to attend the first international Congress on Population Problems.

Then I would like to mention another interesting topic which has international bearings. When some rare but very necessary element is found only in one or two places, should it be in some way internationalized? For instance, much the biggest stock of helium, which is better for airships than hydrogen, because it is not inflammable, is in the United States; and the biggest known supply of radium is in the Belgian Congo.

When it comes, not to valuable substances but to valuable knowledge, scientists almost always co-operate. The co-operation may be indirect, as when the published work of a man in one country puts someone else in another country on the right track. Insulin, for example, could never have been discovered in Canada, as it was, but for much previous patient work by English, French, German, and other scientists. Or the co-operation may be direct. For instance, recent very important work on the vitamin which causes scurvy was carried out by the closest co-operation between Hungarian, British, Dutch, and American workers and institutions.

This looks as if there were really an international spirit among scientists. So there is, among most of them, in times of peace, but as soon as war breaks out they are caught up, voluntarily or involuntarily, in the nationalist compartments of the world's political system. In this respect we are to-day less civilized than a hundred years ago, when, for instance, Sir Humphry Davy was not only allowed to travel through

France in the middle of the Napoleonic wars but actually received with great honours in Paris.

It is, I think, fair to say that while in pure science international co-operation is the rule, in applied science, with a few notable exceptions, it is only just beginning. And I do not mean only in regard to industry and agriculture, I mean also in regard to health, population problems, economics, disarmament, the development of backward areas, and general administration It is just in these fields that a truly scientific policy is most needed, but also just where it will be most difficult to get it, because policy in regard to them is inevitably coloured by the outlook of economic rivalry and political nationalism.

In this we have a good example of the way in which science is limited in its scope and its usefulness by political and social structure, and yet at the same time influences that structure. If science could be applied on the international scale as thoroughly and efficiently as it often is within a single business or a single industry, the most astonishing progress could be made in every field of human activity and human happiness; but it cannot be, owing to the difficulties arising out of the existing world system, with its rivalries and jealousies and exploitations, due to the combination of private profit and national sovereign states.

On the other hand, science *is* influencing the world structure. Its applications are making frontiers look ridiculous, and war ever more and more appalling. Its findings and its inevitably international outlook are gradually penetrating general consciousness and showing up the stupidities of nationalist restrictions and rivalries. Science, as much as any other force, is

making for the breakdown of the system which has given it birth, and in whose bounds it is now confined and cramped. Though for the time being it may be exploited for sectional ends, and may actually intensify present rivalries, in the long run it is hard to see how each new advance in science can help preparing the way, however deviously, and through however much of preliminary chaos, for the world-state.

CHAPTER XIII

SUMMING UP

A Discussion with Professor H Levy

H. L. Well, Huxley, here we are again. I hope you have profited as much as you hoped you would by your tour. Anyway, I want to put some further questions to you.

J. H. All right, Levy. I don't say that I shall be able to answer them, but I'll do my best: so fire away.

H. L. No, I think the best way to begin will be to go over the main points we raised in our opening discussion, and use them as a basis for this. Do you remember the main headings of our first discussion?

J. H. I think so. First there was the problem of how to define science, and then whether there really were two *kinds* of science—pure and applied—or only a gradation between more remote and less remote from practice.

H. L. Yes, and that brought up the question of Universities, and how closely they were linked up with industrial needs, and this led on to the financing of science—who pays for research, and why some branches get much more support than others.

J. H. . . . and whether there are not actual gaps in the organization of research; and if so, why? *À propos* of that, I shall want to bring up the lop-sided character of science in this country, which has impressed itself on me very forcibly.

H L I hope you looked into the points about secrecy in certain kinds of research.

J H Yes, and also, as far as I could, into the international aspects of scientific work. In relation to that, there are some very general questions, such as how to prevent science from collapsing under its own weight, so to speak.

H. L. You mean because of the enormous amount of scientific work that is published?

J. H Yes; the problem of research workers keeping up with the advance of science, even within a small field, is getting more difficult every year.

H. L Then we led up to the final question of whether science could do anything to get us out of our present social and economic mess

J. H. Yes; and you were rather sceptical, I remember. We must have that out properly.

H. L. All right. Let us get down to business. This question of what science really is—I do not think we need waste much time on that now.

J. H. No, we agreed pretty well on a definition—that science is a particular method for getting knowledge of and control over nature, and that the form and direction it takes are largely determined by the social and economic needs of the place and period. What I have seen has confirmed me in that view. We shall never get a proper picture of science and scientific progress unless we take that sort of integrated view, and think of science as a social function, as well as an outcome of man's impulses to understand and control things.

H. L. Integrated view, good. If we are to understand how science operates in society, the effect that

science produces on the world about us, and the counter-effect that society, through its needs, produces on science, we must certainly take this integrated view. That brings up my next point, that you would find it impossible to draw any sharp line between pure and applied science.

J. H. As I said in my discussion with Blackett, I am now more than ever convinced that any such line is merely arbitrary, and that often you cannot draw it at all But, of course, research *can* be at very different degrees of remove from practice; and it is useful to be able to classify the different kinds of research.

For that purpose, I have come to the conclusion that the simple alternative of pure *versus* applied is quite inadequate. You want at least four categories. At one end is *background* research, with no practical objective consciously in view—like atomic physics, or experimental embryology. Then *basic* research, which must be quite fundamental, but has some distant practical objective—as is the case with soil science, or meteorology, or animal breeding. Those two categories make up what is usually called "pure science."

Then you have *ad hoc* research, with an immediate objective, like research on discharge tubes for lighting purposes, or on mosquitoes for getting rid of malaria. And finally, what industry calls *development*, or *pilot* research, which is the work needed to translate laboratory findings into full-scale commercial practice.

Of course, these categories all overlap and interlock, but they are convenient pigeon-holes.

H. L. Of course. Then there was the question of science in the Universities, how remote that was from

practice, how far it was concerned with industrial and other practical aims.

J H. Well, so far as I can see, it is interlocked with the rest of the system to a greater extent than I had realized. The number of university departments devoted to applied science is quite large, and is steadily growing; the university departments of pure science often receive big sums from industry or the State; the D S I.R. and the Government departments connected with agriculture at home and in the Colonies provide really a great deal of money for scientific scholarships and research grants tenable at the Universities (though these grants, it should be noted, are often given for work in very pure science: the Government wants good science for practical purposes, but realizes that it will not get it except by promoting the supply of good scientists, irrespective of their bias to pure or applied problems).

H. L. So these matters are all interlocked and interdependent. That brings up the vital question of money. Were you able to find out much about the funds available for science, and to what extent finance —and where it comes from—dictates the course of research?

J. H. That is not so easy as you might think. Of course, you can get all the amounts spent by the Government on research—it just means digging in Blue Books. But then there is all the money spent by private firms on their own research. This is often kept very secret—sometimes because they do not want their competitors to know how much they are doing; and sometimes, I was amused to find out, because they do not want their shareholders to know—the shareholders,

you see, might think research a silly luxury, and become a nuisance at the annual meeting.

As for university research, that is the most difficult of all. If you wanted to know even how much of the Government grant to Universities goes to research, you would have to carry out a special research to find out! And besides that there are general endowments and special endowments and students' fees all contributing their share.

Then research is helped by the hospitals, and by charitable bodies like the Rockefeller Foundation, and special funds like the Cancer Research Fund, and private institutions like the Strangeways Laboratory, and scientific and semi-scientific societies like the British Association or the Eugenics Society.

H. L. Everything tangled up with everything else. But could you not make any estimate of the amounts spent?

J. H. Well, I did arrive at some rough estimates, but I am sure they are *very* rough. However, they are probably good enough to give an idea of the relative amounts of the total spent on research in this country which go to different fields.

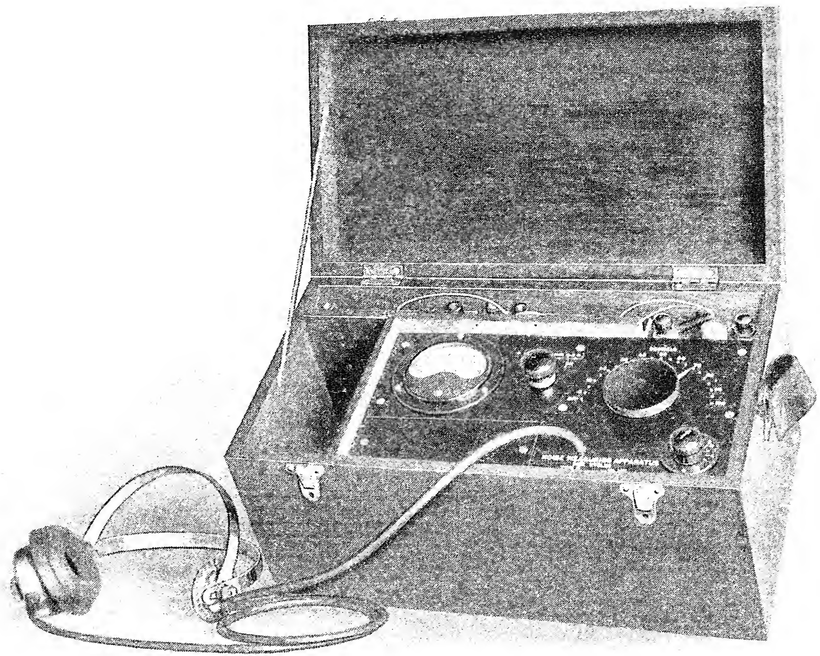
Research directed to industrial needs heads the list—that is, counting the money spent by Government, by university departments of applied science, and by private firms—with, I should say, nearly half the total. Research for the fighting services, not counting mere development, takes about half of what is spent on industry. Research connected with agriculture and related subjects like forestry and fisheries comes next, with a fifth or a sixth of the total; and then research connected with medicine and health, with about an eighth, or even less.

And research in all other branches, together with all background research, probably does not come to a twelfth of the total, though I admit that this item is the most difficult to be sure of. As to the actual amounts, I hardly like to give any figures, as people so often quote rough estimates as if they were ascertained facts. But I should say that the total spent on research in this country is between four and six millions a year, probably nearer the lower figure.[1]

H. L. That means that research directly useful to industrial production receives nearly as much as all other research put together. This is not surprising now that we have seen how closely research is linked up with industrial needs. It does look as if the money consciously or unconsciously guides the course of research, does it not?

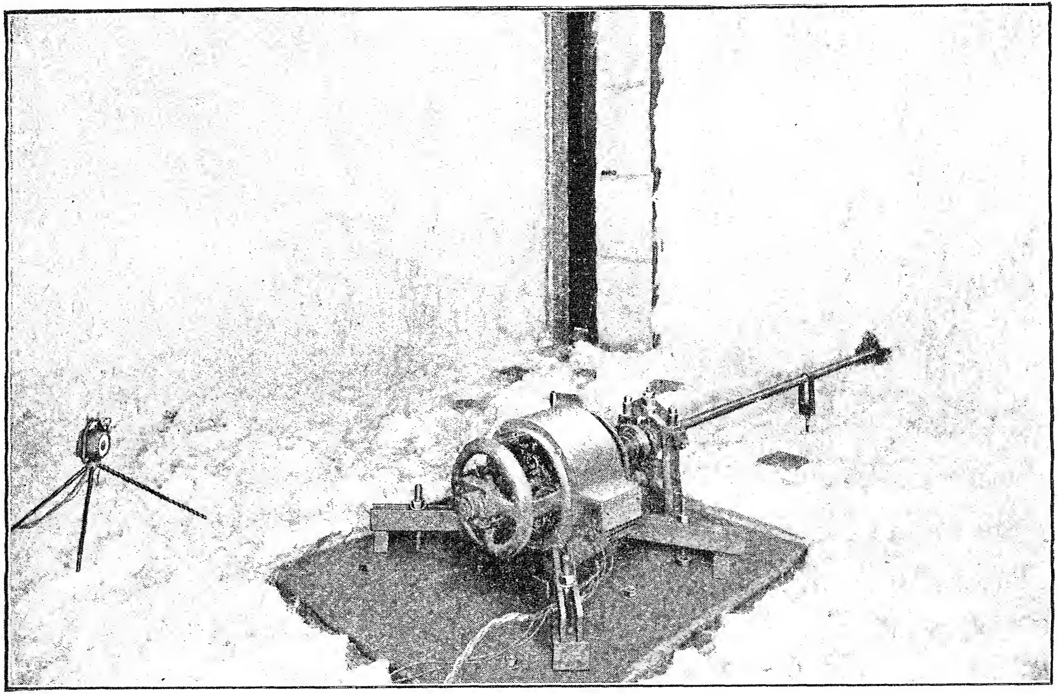
J. H. Yes, definitely, I think. And there is another point that forced itself upon me as I went on my tour. That is, that the bulk of research in progress in this country is organized from the production end—that is to say, it is organized and planned with a view to improving efficiency in technical processes and reducing cost to the producer or to the State. There ought to be much more research organized from the consumption end—directed towards the needs of the individual citizen as an individual and as a citizen.

[1] It has recently been stated in a German publication (see *Nature*, 24 ii 34, p 286) that the amount of money subscribed by industry for scientific research in the United States in 1931 amounted to the colossal figure of $235,000,000 If this is correct, it represents about forty times the corresponding amount spent in Great Britain, or allowing for the difference in population, about sixteen times as much per head! The expenditure of Soviet Russia on its geological survey in 1930 was larger than that of all the other nations of Europe put together.



Science and noise. A portable apparatus which gives an accurate measure of the intensity of sounds and noises. (*See* p. 257.)

By courtesy of Metropolitan-Vickers Electrical Co., Ltd.



Science and noise. A new type of "noiseless" electric motor under test in a sound-testing room lined with wool to prevent echoes and resonance. (*See* p. 257.)

By courtesy of Metropolitan-Vickers Electrical Co., Ltd.

H. L. Would you perhaps explain more fully what you mean?

J. H. Of course, there is some research done from the consumption angle—a lot of the work in the Research Boards under the D.S.I.R. is of this sort—in regard to building, for instance, or radio, and, of course, a greal deal of medical research. But other problems are not taken up at all, or only get tackled piecemeal, because of this general producer bias in research.

Take noise as an example—noise in the streets getting on our nerves all day and preventing us sleeping at night; noise in aeroplanes discouraging people from travelling by air; noise of loudspeakers, children, dogs, and pianos in houses and flats, preventing us enjoying our privacy; noise in industry interfering with the health and efficiency of workers; and so on. Noise, in fact, has become a major problem in our civilization. And yet we only tackle it piecemeal. Actually among the places I have visited myself these last few months I have seen research on noise and how to reduce it going on at central Government institutions like the National Physical Laboratory—work on noise measurement, and on materials which prevent the spread of noise; in Government departments like the Air Ministry—work on silent engines and air screws; in university departments of psychology—research on the psychological effects of noise on manual and mental work; in private firms like Metro-Vickers—work on silent motors for electric fans; in the Industrial Health Research Board and in the Institute of Industrial Psychology—research on the effects of noise in factories on the output and nerves of operatives; in special

research stations like the Building Research Board—work on reducing unnecessary noise in houses; in public utility concerns like the London Passenger Transport Board—work on reducing the noise of tube trains.

If there were any machinery for making the needs of the private individual vocal and effective, instead of this scattered haphazard research, in which anyhow there are a number of gaps, we should have a large-scale concerted attack on the problem You could make out the same sort of case for a concerted attack on diet, and many other problems.

H. L. Yes, but we have already seen the close linkage between science and industry. It does not pay anyone to do jobs like that. There is no remunerative return on it, so it is nobody's business. They are gaps that arise from the fact of our economic system being based on production for profit. But if you want real problems for research of this nature, there are plenty. For example, you talked about how science works for efficiency in production, but if we produce to consume, as well as to sell, is it not efficiency of the production-consumption cycle as a whole that is needed? If we divorce production from consumption, it appears that the more efficient we make production the less efficient frequently is consumption. The more economical a process is in man-power, the less effectively can men consume. No matter how efficient, for example, we may be in bringing to port a herring catch—the actual industrial side may be organized to the highest pitch of scientific management—if the catch is dumped back into the sea because a good enough price is not offered for it, then in spite of all the elaborate care, the

consumption is zero, and the efficiency of the whole process is zero.

J. H. Yes, there certainly is a real problem there.

H. L. The problem can be put in another way. An agricultural labourer, for example, frequently cannot afford to buy the milk he helps to produce; or operatives in a boot factory cannot afford decent boots for their children in spite of all that science has achieved in production alone. We pay workers for production, and let consumption look after itself.

J. H. The same applies to the scientist himself, doesn't it? I expect some of the researchers, say, in the textile field cannot afford all the clothes they would like; and some of them in the laundry research laboratory are probably doing part of their washing at home Anyway, the young scientist is often wretchedly underpaid. In countries like America and Switzerland, he often gets less than a policeman or a skilled artizan—and, in any event, leaving comparisons aside, he often does not get enough to lead the sort of life to which he is reasonably entitled.

H. L. Now to come back to your previous point. What you were really suggesting was to fill in the gaps in research by national directing and planning of research. But with a limited fraction of the national income to be expended on research, and remembering the present close correlation between industry and science, this can hardly be done without the exercise of rather drastic central control over so-called freedom in the industrial enterprise which stimulates this research. But how can this be done without involving ourselves in a dangerous form of nationalism, when there are so many interlocking international connections

and jealousies in the industrial field? And even if research could be considered as divorced from industry, which it cannot, it would be impossible to plan even that internationally on any comprehensive scale when the scientific situation changes so rapidly everywhere.

J. H. Isn't that like saying that a private person should have no plans for the future, because life is so uncertain?

H. L. No An individual plans for himself, up to a point, inside a social structure. Man has already built up society, and he accepts the restrictions that social life imposes on him as assumptions in his individual plans. In the international world there is nothing yet that corresponds to that. The industries of different countries compete with each other for the markets of the world, and any form of National Planning, if it were efficient, must necessarily have the effect of intensifying that competition. The logic of that process seems to imply a repudiation of international restriction, more intense nationalism, self-sufficiency, and probably also war. Anyone who looks at the world now can see the signs already well over the horizon If planning is to take place—and ultimately it will be essential—nothing short of a scheme on an international scale will meet the case, and we are not likely to attain that without a great deal of trouble, or without sweeping away a great number of our most cherished illusions. It does not seem to me at all evident that the best way to attain that end is by striving for *national* planning, no more than you would expect to have a rational régime in Britain itself by endeavouring to make counties like Yorkshire and Middlesex economically self-sufficient. You would simply erect new barriers

that would have ultimately to be destroyed. Scientific planning, whatever kind of society one may want to achieve, must be based on world economics and world natural resources.

J. H. I see. So you would prefer to do nothing for the moment, while waiting for a revolution or whatever will allow your doing things on a world-scale. I prefer to make a start on what lies ready to hand.

H. L. On the contrary, I see plenty of things to be done in the meanwhile. One of them is just what we are doing now: trying to shed daylight on social darkness, in order that people may appreciate the logical outcome of the policies they are initiating; that must be a preliminary to all planning. It is futile simply to take up blindly what lies ready to hand, as you will agree. As for the revolutionary way out, I should hate that; but once more, as with all scientific problems, it is not a question of *our* feelings, but what is the logic of the policy adopted. As I have said before, *national* planning in a world of fierce competition for markets implies repudiation of international restriction, dangerous nationalism, isolation and self-sufficiency, and possibly war. War in the present state of Europe seems to me to mean revolution in most industrialized countries. I would a thousand times rather have a rational than an irrational way out from the present *impasse* to the international solution, if that is possible; and it seems to me we are all heading straight for the irrational way, the intensification of nationalism. National planning in a competitive world I see as one of the steps in that direction. It may be inevitable, it may be simply the inexorable logic of social transformation which we human beings work out in our blundering

way, and of which we are the victims. To me it is no solution, but the next step towards more acute crises.

Nevertheless, I agree that it would be a good thing to know, among other things, what the "map" of scientific work looks like both nationally and internationally. If we could have an investigation on an international scale, similar to what you have been doing so fruitfully on a national one, we might begin to understand more clearly the nature and extent of the social forces at work, and something even of the dynamic of society itself. In that field we are blundering about almost in scientific darkness. The "shape" of scientific research, for example, in a country primarily agricultural, would be quite different from that in an industrial country, wouldn't it? We might then be able to see more clearly the nature of the linkage between industry and science at any period, and why research in Britain has taken on its particular shape.

J. H. I am rather interested to hear you take this attitude—I should have thought your sympathies were all for the socialist outlook, and that this implied more rather than less central control and centralized planning, in science as in everything else. It certainly has in Russia, has it not, where the scientific programme is an integral part of the general Plan? Personally, though I am a firm believer in properly-conducted planning, I am all against having it too embracing and too rigid. There should be an "unplanned zone" in every field, to give scope to human originality and initiative. In this country, after all, it is possible for private people to put up money for research in fields which they think need looking into, but which are officially neglected—

in an earlier discussion I instanced the example of research into the scientific bases of birth control, and it is also possible for an individual worker in pure science at a University to undertake research on whatever aspect of his subject he likes, irrespective of official views. In a socialist state like Russia, there is a real danger that certain fields may be wholly neglected because the authorities are not interested in encouraging them.

H. L. Well, of course these things can be done in Russia, because the whole economy of Russia is different. As a vast country rich in natural resources she is striving to make herself almost entirely self-supporting in what is to her a hostile world. She is striving to eliminate the "profit-making" element from her economic system, and therefore her whole approach to these questions rests on a different series of assumptions from those accepted as basic in other countries. The difference is obvious from the fact that whereas every other country is terrorized at the thought of the dumping of cheap goods within its frontiers, Russia is delighted to have goods cheaply. The reason lies in the different basic social economy on which she is reconstructing her life. As regards "planning," therefore, no comparison at all can be drawn. We cannot isolate "planning" from "planning for what?" I agree at once, of course, that in a country like Russia at present there are certain to be fields of scientific research that will not be developed, since the planning authorities will not be interested in them. That is why I say that each country will give its own peculiar "shape" to the research that is conducted there. We have seen what the map of British research looks like.

J. H. Yes, and a very odd and inconvenient shape it is—entirely lop-sided, with a great bulge on the side of industry, and the physical and chemical sciences which help industry; distinctly undeveloped on the biological and health side, and quite embryonic in the region of the psychological and human sciences. There are actually more trained research workers in chemistry in a single one of the several research laboratories of I.C.I. than there are trained research workers in psychology in the entire country!

H. L. Well, what would you propose should be done about it?

J. H. One obvious thing to do would be to fill the gaps in the existing research structure. At the moment there are Research Councils, with Government backing and Government funds at their disposal, for dealing with science in the fields of industry, medicine, agriculture, and the fighting services. Pure science is looked after to a considerable extent by the Government Grant to Universities, and by the Royal Society, though here again there is little attempt at central co-ordination, such as is done, for instance, by the National Research Council in the United States. But when we come to the remaining fields of human activity, there is nothing. There is an Economic Advisory Committee, but no Economic Research Council to plan and finance concrete research in the economic field; and as for Social Science, not even an advisory committee exists. Is not this field sufficiently important to have a Research Council of its own?

H. L. Well, it seems to me that you are just suggesting putting up bits of administrative and research machinery when there is really no motive power to

drive them. For instance, you have just been telling me how few psychologists and sociologists there are in the country. In the first place, where would you get your trained workers to do the research in the human field? Who is going to apply their results to social practice?

J. H. Rome was not built in a day. But just as the Russian Government is making desperate efforts to create the technicians and industrial scientists whom it lacks, so in this country you could do a great deal, as Sir Josiah Stamp said in an address to the British Association this year, to canalize the scientific brains of the rising generation away from the sciences of lifeless matter and into the biological and human sciences. You could do this by altering the number of scholarships given for different branches of science, and by altering the science curriculum in schools and universities.

H. L. That is all very well; but if you did succeed in getting a supply of good research workers trained in these sciences, who is going to pay them to do their research? Why should not they just find themselves unemployed—I cannot see any reason why the country, as at present organized, should use their services.

J. H. All the same, up to a point, supply does stimulate demand, and the nature of the educational curriculum undoubtedly can help to change the balance between subjects. I taught for some years in an American university, and in that country not only does biology occupy a more prominent position in schools than it does here, but also it happens, for rather accidental reasons of educational organization, that biology can and does have an important place

in a general college education, whereas, for equally accidental reasons, it does not here. The result has been that there are many more people engaged in teaching biology at universities and colleges; and as research is part of a university teacher's job, there is a much greater volume of biological research over there than here.

H. L. However, I do not believe you can do very much in those ways to fill the gaps in research. That will only come when bitter economic necessity calls out for social and psychological research on a large scale, and the way is open to apply it. But there are lots of other questions I want to ask you Science and war, for instance. Were you able to find out anything about the attitude of scientists engaged on war research towards their work?

J. H. Well, in aeronautical research, for instance, all the men I talked to were strong on the point that their work was just as useful for civilian flying as for war.

H. L. Yes; and what about the men engaged on other types of war research? Judging by my experience, I should say that most of them just acquiesced in doing the bits of research as they came along, and were consciously, or more usually unconsciously, just functioning as a part of the State machine.

J. H. Yes, I think that is fair for a good many; though I should say quite a number felt some sort of conflict, and were subject to divided loyalties, meanwhile getting on with their job. After all, there are no other attitudes, unless you are going to be completely loyal to one of the conflicting interests involved, and become either a conscientious objector or else an out-and-out revolutionary.

H. L. These men, of course, occupy a peculiar position in the profession, since much of their work is secret. It would be interesting to know what steps are taken to safeguard the professional interests of such scientific workers. If they cannot publish their work in the ordinary way, they must be handicapped in seeking other appointments, and no public credit can be given to them for the work they have done.

J. H That is not so, of course, if they are employed by a very large firm or a Government department, in which they can receive advancement on the basis of their secret work. On the other hand, as I discovered rather to my surprise, many Universities grant research degrees on work which never will be published, although it meets the standard requirements of being "suitable for publication."

H. L. I see. So that the higher branches of our educational system adjust themselves to this apparent need for secret research, whether for industry or war.

J. H. True enough; but, on the other hand, really fundamental research is rarely kept back from publication, at any rate for long; and, anyhow, secrets tend to leak out.

H. L. And, of course, the patent system, I suppose, allows some applied science that would otherwise be kept secret to be published.

J. H. All the same, I did come across some curious examples of wholesale secrecy. In one government-aided institution, for instance, I was told that it would be against the national industrial interests even to let it be known that a lot of research was being carried on, much less to describe any of it!

H. L. So once more we see science fulfilling a

nationalist function. I see that at a reception a few months ago, a speech by a well-known Cabinet Minister, lauding the part played by scientists and their research in providing new weapons for the bitter struggle for international markets, was loudly applauded by the scientists present. I think it is not an exaggeration to say that this incident indicates how closely scientific research is associated with the needs of capitalist production. Critics of our social system often refer to it as "bourgeois" or "capitalist science."

J. H. Anyhow, if the Nazis in Germany continue to have their way, there will soon be a "Nazi" brand of science. I was reading an article in a German scientific journal recently in which the President of the German Chemical Society asserted definitely that they could not get good chemistry, whether pure or applied, without having a National-Socialist attitude to their work. I am not quite sure what he meant, but that is what he said!

H. L. All the same, you know, there is an interesting reflection in connection with that. If science is as closely linked up with the industrial and social structure as appears, it is clear that the types of problem generally studied will largely reflect that bias. That is to say, the "spread" of science as we know it, the fields that are stressed and those left almost untouched, are likely to be different from what they would have been under a different form of social background.

Try to imagine, for example, science being "begun" simultaneously and independently ten years ago in, say, Soviet Russia and in the U.S.A., and going on, say, for fifty years. The spread of scientific knowledge in the two countries would be totally different, for the fields

of science and the practical problems they would find it necessary to explore and to treat scientifically would be different. Thus the picture of Russian socialist science would be quite different from that of American capitalist science. This suggests that a rather cautious attitude should be adopted on the part of those who seem to imagine science as a sort of idealized knowledge remote from the nature of the social background, and, still more, remote from such things as the struggle for international markets and nationalism.

J. H. That is very interesting. You mean that the *direction* taken by science would be different in a capitalist and a socialist society. The conclusions arrived at in either case would, of course, be scientifically valid in the other type of society, but they might not have been arrived at by it; and even when arrived at in one, they might not be found useful or interesting in the other. All the same, historically I feel it is probably true that science more or less had to develop as it has done. At least it seems clear that the great impetus given to research and invention by the profit motive and national commercial needs was responsible for the rapid rise of natural science during the last three hundred years. And now, thanks to that, we have entered on a new phase—what some writer has well called "the invention of Invention." We have found out that science is the best instrument for acquiring knowledge and power. We have realized that science pays, and that it can be profitably applied in any and every field. We have started to organize scientific research. Once this stage has been reached, it seems to me the next step is to apply science all round, and not merely to the problems where it will yield an

immediate money profit. But I do not think we could have reached that stage without the profit incentive operating in an individualist social structure.

H. L. Well, of course, things would have been different; but explain a little further

J. H. Well, look at the absence of scientific progress in other periods and places—in India, for instance, or in China.

H. L. That is true enough, although it is also true that other factors, such as cheap human labour, also come in in those countries instead of mechanization. But to go back to my earlier points: it is clear, at least, how difficult it is to talk of international science, except for those developments that are either so basic that all national sciences need them, or that are so general, and therefore, if you like, so fundamental, that they do not matter for nationalist purposes.

J. H Well, I don't know that I agree with you. For one thing, science, as we agreed, has its own momentum, and as it progresses it changes the social and economic structure of the country and also people's general outlook. That means that it is always transcending its own limitations and bursting the bonds imposed upon it. In other words, the inevitable logic of this mixture of national and international science is to make the nationalist problem more acute, and so to work up to a crisis at which some revolution or radical change in social structure will be inevitable.

Then do not let us forget that some highly practical aspects of science are already refusing to be confined in the framework of national boundaries. For one thing, really big business is to a large extent international. In some cases big firms have arrangements by which

they share the results of research and divide up the market with agreed spheres of influence. It is well known that something of the sort holds between various powerful industrial firms here and on the Continent. Then there is the work on non-ferrous metals, which I mentioned in the previous chapter, or the work on locusts, in which the Italians and the French are co-operating whole-heartedly with our research centre in London. And there is the wonderful work of bodies like the Rockefeller Foundation, which, though it is financed wholly by American money, supports fundamental science in every civilized nation, and has, for instance, carried out a great campaign of applied science against yellow fever which has benefited the whole world.

H. L. Yes, but even those international aspects necessary for national purposes are often difficult to arrange because of national jealousies.

I remember from my own experience the difficulty there was in trying to arrange for an international testing of model aeroplanes in order to compare the accuracy of the wind-tunnels that are used in such test work. So that even standards are sometimes difficult to arrange, because the nations concerned are afraid to give away their weaknesses to their rivals.

J. H. All the same, you can't get over instances like the Rockefeller Foundation's yellow-fever work. And in the field of standardization, a lot of useful international standards *have* been arranged. Leaving out of account the more mechanical side, like the standardizing of world time or of world measurements of length and mass, there is all the work done in standardizing vitamins and drugs and antitoxins, which is most important for health

H. L. But perhaps a certain minimum standard of health is basic and indispensable for every nation.

J. H. I'm not so sure. Health *should* be indispensable, but it is just a fact, isn't it, that a great many people have to dispense with it? And you could use scientific knowledge about health for nationalist purposes all right Look at those investigations I spoke of in my last chapter, on East African native tribes, which showed what an enormous improvement in physique and health and average length of life you could effect by quite simple measures concerning diet, prevention of parasitic disease, and child welfare. If one of the big Colonial powers in Africa were to apply all the resources of science to raise the health and the energy and the numbers of its native populations, and another were to do nothing, but just let matters slide, the former would soon enjoy an enormous advantage.

H. L. Yes, the fact is that if industry really needed a healthy population we would have one. During the war, of course, we realized the need for an A.1 rather than a C.3 nation, but it is not pursued in the spirit of a business venture.

J H. Well, there is the Ministry of Health and the Medical Research Council and the Medical Officers of Health all over the country. Surely these are pretty business-like.

H. L. Oh, yes; but notice that even the scientific investigations that are made into such matters as family budgets pose the problem in terms of the minimum for which survival is possible, which seems to me very unsatisfactory. The wage-earning part of the population, in other words, is not treated as a

potential and expansible market for commodities, but as a burden.

J. H. That is where science links up with economics, isn't it? However, you have brought up the problem of population, and that is something which *could* be studied scientifically.

H. L But what can science do in practice about the control and design of population, considering the fact that a planned population has to fit a situation a whole generation ahead, while it is so difficult to make anything of the nature of a social prediction?

J. H. I do not think we could say exactly what science could do in this field until we have tried applying it. In general, my point is that most people seem to think that the size of your population is something given—an act of God, so to speak—and that you have just got to accept it and try to fit your social and economic structure to it. Whereas, in reality, population could be controlled—to some extent, at least—and to an extent not much less than the extent to which you could possibly control your economic system. So that what we ought to aim at is to adjust things both ways—fit the population to the economic system as well as vice versa.

H. L. I agree, of course, that there is a real mutual interaction and interdependence between a country's economic resources and the number of people in it, and that it is this interaction we ought to study with a view to control.

J. H. Yes, certainly. To take only one point: how many people realize that within a dozen years the population of this country will quite certainly be going down, and may proceed to continue going down at a

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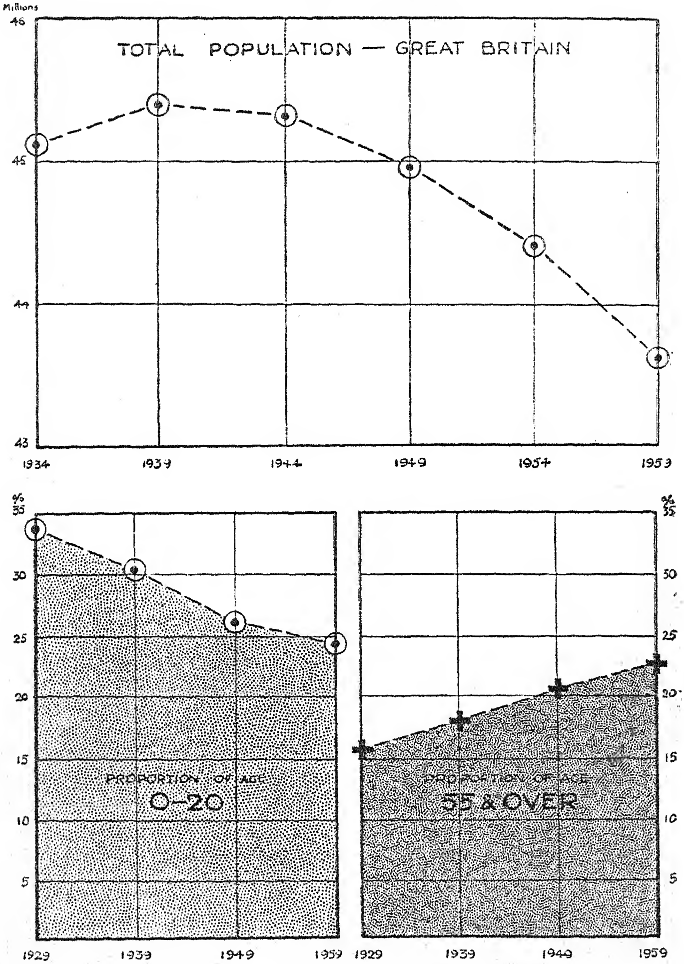

Above, a curve showing the probable total population of Great Britain, assuming no net emigration, for the next 25 years.
Below, the probable change in the proportion of young people up to the age of 20 (left) and of old people above the age of 55 (right), calculated as percentages of the total population. (Based on figures issued in *Planning* No. 4, 6th June, 1933.)

very rapid rate? We have been suffering from over-population, but within half a century we may quite possibly find ourselves being frightened by the bogey of under-population. Ought we not to make a scientific study of the methods by which populations can be checked or encouraged—birth-control methods and how to get them across to the poor and uneducated; family allowance schemes; bonuses or tax rebates for children; and so on? At the moment these are getting looked at from a merely political angle, or hushed up because they come under some religious tabu. Why, the mere suggestion that abortion could even be studied scientifically as a possible method of checking over-population is enough to make a great many quite responsible people explode with indignation.

H. L. And I suppose you as a biologist have views on heredity in man, and the whole question of the quality of population as well as its quantity?

J. H. Indeed I have To my mind, one of the most fundamental problems for scientific study is that thrown up by Professor R. A. Fisher recently, when he asserted that a society like ours, based on individualism and commercialism, and with some sort of ladder of opportunity for talent to rise and inefficiency to sink, is inevitably, and of its very nature, the reverse of eugenic—*dysgenic*, as the technical term is I cannot go into all his argument here, but he makes out a strong case to show how in such circumstances inherited qualities making for rise in the social scale, automatically tend to get linked with inherited qualities making for reduced fertility, and vice versa That would mean that, generation by generation, we were steadily reducing the average level of our

population as regards some of its most desirable inborn qualities.

H L. I'm afraid I disagree with a great deal of that, but we cannot argue that here.

J. H. I'm afraid not, my dear Levy. But you will agree that the problem of eugenics is a vital one and deserving of intensive study, instead of being entirely neglected by the powers that be, as it is at the moment?

H. L. Yes, it needs study all right. The size and the quality of a population depend on the social ecology, the social background, what society encourages and supplies. And that again depends on the population. The two go hand in hand, and will have to be changed together, but it seems to me quite unlikely that effective steps to deal with population will be possible unless we first can exercise control over the social background: and exercising control over society is vastly different from having scientific knowledge how society might be changed by the scientist if he were given control.

J. H. Anyhow, I think it quite certain that science, if it were allowed a free hand, could control the evolution of the human species.

H. L. That may be so, but one of the first questions we have to ask as soon as we have accumulated adequate scientific knowledge, even if we can ever have it on this matter, is, What objective have we? Can scientific men lay down an objective? We are to use science and scientific methods, but for what? What kind of society do we want? What kinds of society are possible at all? That is too important a question to leave to scientists. Science is used, when it is used, to develop and further

the ends of present-day society, and is restricted and circumscribed by the possibilities inherent in that social order You must in your survey have come across many illustrations showing how scientific investigation and scientific practice are cramped and confined in this way For instance, there are many things—health is one—which, while apparently desirable on general grounds, are not pursued because it does not pay those who hold the economic power to develop them.

J. H Yes For example, I found a case where a scientist with a big programme for improving livestock found how difficult it was to put his admirable ideas into practice, and as a result is confining his practical activities largely to answering routine questions from breeders, while concentrating his research work on pure genetics very remote from practical application.

H. L. Precisely But if these are the sort of difficulties that face you in connection with such a comparatively simple problem as the breeding of animals, where the scientist has some control, if not much, of the experiment, how can we possibly regard the problem of designing a human stock suited to a humanely desirable environment as a feasible task, especially since the social background in which human beings live is changing all the time? With all the best will in the world, you can do nothing more than study objectively the behaviour of humans in the present chaos.

J. H. That is just my point. You can reduce the chaos by scientific study. For instance, you could study the eugenic or dysgenic effects of different kinds of social structure, and of different financial and social measures like income tax, free education, or family allowances.

H. L. That gets me back to my earlier point. If we are talking of the use of science for designing a new society, we must ask ourselves what kind of a society we want to design, and whether it is a physically and psychologically possible one. That is to say, we have to study our desires in this matter, our prejudices—our bias, if you will—and deliberately set about acquiring power in order to create, with the help of science, such a biased society. Scientists, like everyone else, cannot get away from prejudice and bias bias has to be used Nor is the power to create a new society vested in their hands.

J. H. Using a bias . . . what exactly do you mean?

H. L. Well, in the first place we have to get rid of this myth of impartiality. We have to recognize that whatever we set about doing is simply a method of fulfilling the desires of some person or group, and the *scientific* question we can ask is, Whose has it been in the past, and whose is it to be in the future? Once that is settled, we can call in the scientists to build up the material environment suitable to that specification, the educationist to effect the adjustment in the individual to that social background. Thus it must always be science, education, art, for a purpose But science proceeds by attempting to eliminate this purposive feature. It treats questions objectively, and therefore *in itself* cannot offer any solution to our social ills. It can only be called in, like the builder or the plumber, once we know the kind of house we want—or the type of water system. It is for that reason that I think the recent proposal to get scientific bodies to make pronouncements *qua* scientists on matters of social or industrial policy must be doomed to failure, since their

statements must necessarily be coloured by their social prejudices, and as soon as they become aware of them, they will separate into different political camps.

J. H. Well, I cannot help feeling you are being too gloomy, and thinking too much about the particular limitations of science, and not enough about its general qualities, which more or less inevitably cause it to transcend its limitations. I know it is a slow job, but a biologist, who has to study evolution, gets used to slow jobs!

With regard to the scientific bodies, I cannot help feeling that as long as they are not too ambitious, what they are aiming at is all to the good. Personally, I know that looking at science in its relation to social needs, as I have had to do for this survey, has cleared my own mind a great deal; and if the scientific movement in this country can do this and become conscious of itself, and of its limitations, and of its relation to the economic driving forces of society, that will be a very valuable step. The chief moral of this book, it seems to me, is that science is not the disembodied sort of activity that some people would make out, engaged on the abstract task of pursuing universal truth, but a social function intimately linked up with human history and human destiny. And the sooner scientists as a body realize this and organize their activities on that basis, the better both for science and for society.

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